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A

COMPENDIOUS TREATISE

ON THE USE OF

Globes & Maps;

COMPILED FROM

THE WORKS OF KEITH, FERGUSON, ADAMS, HUTTON, BRYAN, GOLDSMITH, AND OTHER EMINENT AUTHORS;

BEING A

PLAIN AND COMPREHENSIVE INTRODUCTION

TO THE

PRACTICAL KNOWLEDGE OF

Geography and Astronomy.

CONTAINING ALSO

A brief view of the Solar System; a variety of Astronomical Tables; numerous Problems, for the exercise of the Learner, &c.

BY JOHN LATHROP, JUN. A.M.

BOSTON:

PUBLISHED BY WELLS AND LILLY AND

J. W. BURDITT.

1821.

TO THE

REVEREND PRESIDENT,

THE

TRUSTEES AND PROPRIETORS,

OF THE

SALEM-STREET ACADEMY, IN BOSTON:

THE

FOLLOWING TREATISE,

COMPILED FOR THAT SEMINARY,

AND OTHER

SIMILAR INSTITUTIONS,

IS DEDICATED AS A TRIBUTE OF RESPECT

AND AFFECTION,

BY THEIR SINCERE FRIEND, AND

HUMBLE SERVANT,

JOHN LATHROP, JUN.

Exch.
Harvard Univ.
10-26-36

Boston, May 20, 1812.

THE undersigned, your Committee appointed to examine the manuscript presented by Mr. Lathrop, entitled, "A Compendious Treatise on the use of Globes, and of Maps; comprising the elements of Geography and Astronomy, a description of the Solar system, &c.;" have attended to the duty of their appointment, and, beg leave to report, "That, having given the subject a careful review, they are convinced, that it is a work promising much usefulness as an elementary book, on those interesting and important sciences; they, therefore, recommend it to the particular attention and patronage of the associated instructors of youth in the town of Boston; all which is respectfully submitted by your humble servants.

O. CARLETON,
D. ADAMS,
DANIEL STANIFORD.

AT a regular meeting of the Associated Instructors of the town of Boston, &c.—Voted, That the above report be accepted, and that the proposed work be warmly recommended to the public, and that we will exert our influence to procure its introduction into our respective seminaries.

May 20, 1812. EBEN: PEMBERTON, *President.*

A true Copy,

Attest, EPHRAIM H. FARRAR, *Sec'ry.*

PREFACE.

Although many works of standard excellence are extant on the use of the globes, and on the elements of geographical and astronomical knowledge, they are, in general, too expensive for introduction into the Schools and Academies of this country. Books of high reputation on these subjects, are composed in the form of Lectures, or Dissertations; and few can be found, in in which the necessary definitions are sufficiently numerous, plain, and perspicuous for the assistance of the teacher, or the comprehension of the pupil. Besides, in works which are not especially confined to the principles of a single science, an abundance of matter is inserted, which is not only useless, but an incumbrance in the prosecution of a particular object of inquiry. The simple points on which the student wishes to fix his attention, are loosely scattered over the pages of a bulky volume, and are found with difficulty, amidst the theories and hypotheses, logical deductions, poetical embellishments, and moral reflections, with which most of our valuable and expensive publications abound. In the search after articles of elementary instruction, the moments which ought to be employed in trea-

suring them in the memory, are wasted; and the mind becomes fatigued by labours which yield not the expected profits and rewards of sedulous and well-directed exertion. On the other hand, most of the works, whose price is low enough to admit of their being studied as class books in our seminaries, are very defective in many respects. To furnish a cheap and useful manual for the teacher, and for the pupil, has been my endeavour in the following Treatise. It has no claims to public confidence, but such as arise from the credit due to the authors, of whose labours I have availed myself in its compilation. As an Instructor of youth, I have long experienced the want of a concise and familiar introduction to the use of the globes, and of maps, as instruments of indispensible importance in the study of geography and astronomy. In the hope, that this attempt to supply my own need, may be servicable to gentlemen who are engaged in the tuition of youth, and to students in general, I have ventured to publish it in its present form. Should it prove useful—and not only lighten the labour, but facilitate the acquisition of instruction, I shall feel grateful to that Divine Being, who has enabled me to contribute even an humble mite towards enriching the minds of the rising generation.

Salem-Street Academy.
Boston, 1812.

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A

COMPENDIOUS TREATISE, &c.

BEFORE we describe the globes, it will be proper to take some notice of the properties of a circle, of which, a globe may be said to be constituted.

1. A *line* is generated by the motion of a *point*.

2. Let two *points* be supposed, the one moveable, the other fixed.

3. If the moveable point be carried directly towards the fixed point, its motion will generate a *straight* line.

4. If the moveable point be carried round a fixed point, keeping in its course at the same distance from it, a circle, or some part of a circle will be formed, of which the fixed point will be the centre.

5. All straight lines proceeding from the centre to the circumference of a circle, are equal.

6. A right or straight line drawn from the centre of a circle to its circumference, is called radius, or semi-diameter.

7. Every straight line, drawn through the centre of a circle, and terminated by its circumference, is called a diameter.

8. A sphere is a solid body contained under one single uniform surface, every point of which is equally distant from a certain point in the middle, called its centre.

9. An Axis is a real or imaginary line, passing through the centre of a sphere or circle on which

it revolves, or is supposed to revolve. The extremities of an axis are called its poles.

10. A map is a plane figure representing the surface of the earth, or some part of it, being a projection of the globular surface of the earth, exhibiting countries, seas, rivers, mountains, cities, &c. in their due positions.

11. Maps are either universal or particular.

12. Universal maps are such as exhibit the whole surface of the globe, or the two hemispheres.

13. Particular maps are those which represent some particular region, or part of the earth.

14. Charts or sea maps, are those which represent only the oceans, seas, and sea coasts.

15. The latitude of places upon maps is expressed by the figures on their sides. If the figures increase upward, the latitude is north; if they increase downward, the latitude is south.—[See map.]

16. On maps, the longitude of places is expressed by the figures at their top and bottom. When the figures increase to the right, the longitude is east; when they increase to the left, the longitude is west.—[See map.]

17. In maps in general, the upper part is northward; the lower, southward; the right side, eastward; and the left, westward. When constructed in a different manner, the bearings of the map are expressed by a compass, with a fleur de luce pointing to the north, and a cross to the east.—[See map.]

18. Geography is the science which describes the surface of the earth, the constituent parts of which are land and water.

19. The land consists of continents, islands, peninsulas, and isthmusses; and the water of oceans, seas, lakes, gulfs, straits, and rivers.

20. There are two continents: the old or eastern, which contains Europe, Asia, and Africa:

and the new or western continent consisting of North and South America.

21. An island is a portion of Land surrounded by water; as Great Britain, Newfoundland, Cuba, Nantucket, &c.

22. A peninsula is a tract of land almost surrounded by water; as Boston, and the Morea in Greece.

23. An isthmus is a neck of land which joins a peninsula to a continent, or two grand divisions of the same continent together; as the isthmus of Suez which joins Asia to Africa, and that of Darien, which unites North and South America.

24. A cape is a point of land extending far into the sea. If the land be high and mountainous, it is called a promontory.

25. The Ocean is the vast collection of salt and navigable water which encompasses most parts of the earth, and occupies about two thirds of the whole surface of the globe.

26. The great and universal ocean is generally divided into four parts, viz. the Pacific, the Atlantic, the Indian, and the Northern or Frozen ocean. The ocean also takes other names, from the countries on which it borders; as the German ocean, &c. and according to the position of it on the globe, as the northern, southern, eastern, western ocean.

27. The ocean, penetrating the land at several straits, quits the name of ocean, and assumes that of sea, or gulf, as the Mediterranean sea, the Persian gulf, &c.

28. A sea is a smaller collection of water than an ocean, as the Caspian sea, the Baltic, &c.

29. A lake is a large collection of fresh water in the interior of a country; as Lake Champlain, Lake Ontario, &c.

30. A gulf or bay is an arm of the ocean, or of a sea which extends a considerable way into the land, as the Gulf of Mexico, the Bay of Biscay, &c.

31. A strait is a narrow part of the sea, forming a passage from one sea to another; as Davis's Straits, the Straits of Gibralter, &c.

32. The earth is a globular body, whose diameter is about 7964 miles in length, and whose surface contains nearly 200 millions of square miles.

33. *The land* is inhabited by about a thousand millions of human beings.

34. The earth is divided by geographers into four great nominal parts, sometimes called quarters, viz. Europe, Asia, Africa, and America.

35. The foundation of all maps is what is called The projection of the spheres.

36. Of projections there are two kinds, orthographic, and stereographic. The orthographic, supposes the eye placed at an infinite distance in the axis of the circle of projection; the stereographic, supposes the eye to be in the pole of the circle of projection.

37. Mercator's projection supposes the earth, instead of a globular to have a cylindrical figure; in consequence of which, the degrees of longitude become of an equal length throughout the whole surface, and are marked on the map by parallel lines. The circles of latitude are also represented by lines crossing the others, or right angles; but at unequal distances, the degrees of latitude increasing in length, in proportion as they are distant from the equator. A map of the world, therefore, cannot be delineated upon this projection, without distorting the shape of countries in a very extraordinary manner; but the projection is useful in sea charts, as it shews the differ-

ent bearings of places with perfect accuracy, which cannot be done on any other map.

38. Plain charts have the meridians, as well as the parallels of latitude, drawn parallel to each other, and the degrees of latitude and longitude equal to those at the equator.

39. The Armillary sphere is an astronomical instrument, representing the several circles of the sphere in their natural order, serving to give an idea of the office and position of each of them. It is thus called, as consisting of a number of circles or rings, which were called by the Latins, armillæ, from their resembling bracelets, or rings made for the arm.—[Fig. 7.]

Definitions of Terms necessary to be understood in the solution of Problems on the Terrestrial and Celestial Globes.

40. The terrestrial globe is an artificial representation of the earth. In the figure 1, the globe is represented out of its stand, that the different circles, &c. may be distinctly seen.

41. The grand divisions, different empires, kingdoms, countries, chief cities, oceans, seas, rivers, &c. are represented on the terrestrial globe, according to their relative situations on the real globe of the earth.

42. The diurnal motion of the terrestrial globe is from west to east.

43. The axis of the earth is an imaginary line passing through the centre of it, on which it is supposed to turn, and about which all the heavenly bodies appear to have a diurnal revolution.

44. The axis of the earth is represented by the wire which passes from north to south, through the middle of the artificial globe.—[Fig. 1.]

45. The poles of the earth are the two extremities of its axis; one of which is called the north or arctic; the other, the south or antarctic pole.—[Fig. 1.]

46. The celestial poles are two imaginary points in the heavens, exactly above the terrestrial poles. Or, if the axis of the earth were prolonged until it came in contact with the starry heavens, it would touch the celestial poles in two points, one of which, would be within two degrees of the pole star,* in the end of the tail of the Little Bear.

47. The brazen meridian is the circle in which the artificial globe turns, and is divided into 360 equal parts, called degrees.—[Fig. 1.]

48. Every circle is supposed to be divided into 360 degrees; each degree into 60 minutes, and each minute into 60 seconds.

49. A degree of a great circle in the heavens is a space nearly equal to twice the apparent diameter of the sun, or to twice that of the moon, when considerably elevated above the horizon.

50. The degrees in the upper semi-circle of the brazen meridian, are numbered from 0 to 90 from the equator towards the poles, and are used for finding the latitudes of places.

51. On the lower semi-circle of the brazen meridian, the degrees are numbered from 0 to 90, from the poles towards the equator, and are used in the elevation of the poles.

52. Great circles divide the globe into two equal parts, as the equator, the ecliptic, the rational horizon, and the brazen meridian, when assumed

* The Pole star is a star of the second magnitude, near the north pole, in the end of the tail of the Little Bear. Its mean right ascension, for the beginning of the year 1804, was 13° 14′ 43″ and its declination 88° 14′ north. Mr. Bowditch gives its right ascension in time 52′ 15,″ for 1800.

as the meridian of any particular place; and the colúres on the celestial globe.*

53. The equator is a great circle of the earth, equidistant from the poles, and divides the globe into two hemispheres, northern and southern.—[Fig. 1.]

54. The latitudes of places are counted northward and southward from the equator; and the longitudes of places are reckoned upon it eastward and westward.

55. The equator when referred to the heavens, is called the equinoctial, because when the sun appears in it, the days and nights are equal all over the earth, viz. 12 hours each.

56. The first meridian, is that from which geographers begin to count the longitude of places. In English maps and globes, the first meridian is a semi-circle supposed to pass through London or the royal observatory of Greenwich.

57. Meridians, or lines of longitude, are semicircles, extending from the north to the south pole, and cutting the equator at right angles.—[Fig. 2.]

58. Every place on the globe, is supposed to have a meridian passing through it, though there are 24 only drawn on the artificial globe; the deficiency is supplied by the brass meridian.

59. When the sun comes to the meridian of any place (not within the polar circles,) it is there noon or mid-day.

60. When the brass meridian stands over any particular place, representing its meridian, it is considered as a great circle, dividing the globe into the eastern and western hemispheres.—[Fig. 1.]

61. The ecliptic is a great circle in which the sun makes his apparent annual progress among

* Secondaries to a great circle, are great circles which pass through its poles, and consequently must be perpendicular to it.

the fixed stars; or it describes the real path of the earth round the sun, and cuts the equator, when drawn on the terrestrial globe, in an angle of 23° 28′. The points of intersection are called the equinoctial points.—[Fig. 2.]

62. Small circles divide the globe into two unequal parts.

63. The tropics are two small circles parallel to the equator at the distance of 23° 28′ from it; the northern is called the tropic of cancer, and the southern, the tropic of capricorn.—[Fig. 2.]

64. The tropics are the limits of the torrid zone.

65. The polar circles are small circles parallel to the equator, at the distance of 66° 32′ from it, or 23° 28′ from each pole. The northern is called the arctic; the southern, the antarctic circle.—[Fig. 2.]

66. Parallels of latitude are small circles drawn through every ten degrees of latitude, on the terrestrial globe, parallel to the equator.—[Fig. 2.]

67. Every place on the globe is supposed to have a parallel of latitude drawn through it, though there are, in general, only sixteen parallels drawn on the terrestrial globe.

68. The hour-circle on artificial globes, is a small circle of brass, with an index fixed to the north pole. This circle is divided into twenty-four equal parts, correspondent to the hours of the day; and these again are subdivided into halves and quarters.

69. The equator is also an hour circle, being on the best globes so divided by meridian lines, drawn through every fifteen degrees of longitude, as to answer every purpose to which the brass circle can be well applied.

70. The ecliptic is divided into twelve equal parts, called signs, each containing thirty degrees. The sun makes his apparent annual progress

through the ecliptic, at the rate of nearly one degree in a day.—[Fig. 2.]

71. The names of the signs and their characters, and the days on which the sun enters them, are as follow:

Vernal Signs.

♈ Aries, the ram,—21st of March.
♉ Taurus, the bull,—19th of April.
♊ Gemini, the twins,—20th of May.

Summer Signs.

♋ Cancer, the crab,—21st of June.
♌ Leo, the lion,—22d of July.
♍ Virgo, the virgin,—22d of August.

Autumnal Signs.

♎ Libra, the balance,—23d of September.
♏ Scorpio, the Scorpion,—23d of October.
♐ Sagittarius, the archer,—22d of November.

Winter Signs.

♑ Capricornus, the goat,—21st of December.
♒ Aquarius, the water-bearer,—20th of January.
♓ Pisces, the fishes,—19th of February.

72. The vernal and summer signs are called northern signs; because when the sun is in any of them, his declination is north.

73. The autumnal and winter signs are called southern signs; because when the sun is in any of them, his declination is south.

74. The vernal and autumnal signs are called ascending signs; because when the sun is in any of them, his declination is *increasing*. The summer and winter signs, are called descending signs; because when the sun is in any of them, his declination is *decreasing*.

75. Declination of the sun, a star, or planet, is its distance from the equinoctial, northward or southward.

76. When the sun is in the equinoctial he has no declination, and enlightens half the globe from pole to pole. As he increases in north declina-

tion, he gradually shines further over the north pole, and leaves the south pole in darkness: in a similar manner, when he has south declination, he shines over the south pole, and leaves the north pole in darkness.

77. The greatest declination the sun can have, is 23° 28′—the greatest declination a star* can have is 90°—and that of a planet, 30° 28′ north or south.

78. The horizon is a great circle, which separates the visible part of the heavens from the invisible. This circle, when applied to the earth, is distinguished by the names rational and sensible horizon.

79. The true or rational horizon is an imaginary plane passing through the centre of the earth. It determines the rising and setting of the sun, stars, and planets.

80. The sensible, or visible horizon, is that which terminates our view, and is represented by that circle which we see in a clear day where the earth, or sea, and the sky seem to meet.

81. The wooden horizon, circumscribing the artificial globe, represents the rational horizon on the real globe. This circle is divided into several concentric circles, which are arranged on Bardin's new British globe, in the following order: [Fig. 1.]

82. The first circle is marked amplitude, and is numbered from east and west, towards the north and south, from 0 to 90°.

83. The second circle is marked azimuth, and is numbered from the north and south points of

* The star, called the pole star, is not exactly over the pole; but, being a star of the second magnitude, and nearer than any other remarkable star to the pole, it is very useful in navigation, in determining the latitude of places, &c. especially as its declination being known, its complement of latitude can be exactly ascertained. Its declination is 88° 14′ north.

the horizon, towards the east and west, from 0 to 90°.

84. The third circle contains the thirty-two points of the compass, divided into half and quarter points. The degrees in each point are to be found in the azimuth circle.

85. The fourth circle contains the twelve signs of the zodiac, with the figure and character of each sign.

86. The fifth circle contains the degrees of the signs, each sign comprehending 30°.

87. The sixth circle contains the days of the month, answering to each degree of the sun's place in the ecliptic.

88. The seventh circle contains the equation of time, or the difference of time between a well regulated clock and a sun dial. When the clock ought to be faster than the dial, the number of minutes expressing the difference has the sign + before it; when the clock ought to be slower, the number of minutes has the sign — before it.

89. The eighth circle contains the twelve calendar months of the year.

90. The cardinal points of the horizon are east, west, north, and south.

91. The cardinal points of the heavens are the Zenith and Nadir, and the points where the sun rises and sets.

92. The cardinal points of the ecliptic are the equinoctial and solstitial points, which mark the commencement of the four seasons of the year.

93. The cardinal signs are ♈ Aries, ♋ Cancer, ♎ Libra, and ♑ Capricorn.

94. The zenith is a point in the heavens, exactly over our heads, and is the elevated pole of our horizon.

95. The nadir is a point in the heavens, exactly under our feet, being the depressed pole of our

horizon, or the elevated pole of the horizon of our antipodes.

96. The pole of any circle is a point on the surface of the globe, 90° distant from every part of the circle of which it is the pole. Every circle on the globe has two poles diametrically opposite to each other.

97. The equinoctial points are Aries and Libra, where the ecliptic cuts the equinoctial. The point Aries is called the vernal, and Libra, the autumnal equinox. When the sun is in either of these points, the days and nights, on every part of the globe, are equal to each other.

98. The solstitial points are Cancer and Capricorn. When the sun is in either of these points, the variation in his greatest altitude is scarcely perceptible for several days; because the ecliptic, near these points, is almost parallel to the equinoctial, and therefore the sun has nearly the same declination for several days.

99. When the sun enters Cancer it is the longest day to all the inhabitants on the north side of the equator, and the shortest day to those on the south side. When the sun enters Capricorn it is the longest day to those who live on the south, and shortest to those who live on the north side of the equator.

100. A hemisphere is half the surface of a globe. Every great circle divides the globe into two hemispheres.

101. The horizon divides the upper from the lower hemisphere in the heavens; the equator separates the northern from the southern on the earth; and the brass meridian, standing over any place on the terrestrial, or over any star or other heavenly body on the celestial globe, divides it into the eastern and western hemispheres.

102. The mariner's compass * is a representation of the horizon, and is used by seamen to direct and ascertain the course of their ships. It consists of a box which contains a paper card, divided into thirty-two equal parts, fixed on a magnetical needle that points towards the north.

103. The variation of the compass is the deviation of its point from the correspondent point in the heavens. When the north point of the compass is to the east of the true north point of the horizon, the variation is east; if it be the west, the variation is west.

104. The magnetic needle does not always point directly to the north, but is subject to a small annual variation. At present, in England, the needle points about 24° to the westward of north;—in Boston the variation is, in 1812, 4° 48′ west.

105. Latitude of a place on the terrestrial globe is its distance from the equator, in degrees, minutes, or geographical miles; and is reckoned on the brass meridian, from the equator toward the north or south pole.

106. The quadrant of altitude is a thin slip of brass divided from 0 to 90°, and sometimes downward to 18°; and, when used, is generally screwed to the brass meridian. The upper divisions are used to determine the distances of places on the earth; the distances of the celestial bodies, their altitudes, &c. and the lower divisions are applied to find the beginning, duration, and end of twilight.

107. Longitude of a place on the terrestrial globe, is the distance of that place from the first meridian, reckoned in degrees and parts of degrees, on the equator.

108. On most English maps and globes, the first meridian is drawn through London, or the

* See Skeleton Map.

royal observatory at Greenwich, and longitude is counted eastward and westward, half round the globe; consequently, on such maps and globes, no place can have a greater longitude than 180°. The figures expressing these degrees are placed *immediately* above the equator.

109. On most maps, sea charts, and globes, made on the continent of Europe, geographers construct them either with the first meridian drawn through the capital of the country in which they are made, or through Ferro, one of the Canary islands in the Atlantic ocean. Most of the continental geographers reckon longitude eastward, from their first meridian, round the globe. For the accommodation of such as prefer this way of reckoning, a second row of figures is placed on the terrestrial globe, over the row nearest to the equator.

110. There are no places upon the surface of the earth, through which meridians may not be conceived to pass. Every place, therefore, is supposed to have a meridian passing over its zenith, from north to south, and going through the poles of the world.

111. To find the longitude of a place is to discover what degree of the equator the meridian of that place crosses.

112. All places that lie under the same meridian are said to have the same longitude.

113. Upon the terrestrial globe, there are twenty-four meridians drawn, dividing the equator into twenty-four equal parts, which are the hour circles of the places through which they pass.

114. The distance of these meridians from each other is 15°, or the twenty-fourth part of 360°: 15° of longitude are equal to 1 hour; and 1° of longitude to 4 minutes of time; $\frac{1}{2}$° to 2 minutes, and $\frac{1}{4}$° to 1 minute.

115. * Degrees of longitude may be turned into time by multiplying by 4; observing that minutes or miles of longitude produce seconds of time, when multiplied by 4, and degrees of longitude, when multiplied by 4, produce minutes of time.

116. † Time may be reduced into degrees, &c. by multiplying them by 10, and increasing the product one half.

117. Apparent noon is the time when the sun comes to the Meridian, viz. 12 o'clock, as shewn by a correct sun dial.

118. True or mean noon is 12 o'clock, as shewn by a well regulated clock, adjusted to go twenty-four hours in a mean solar day.

119. The equation of time at noon is the interval between the true and apparent noon; it is the difference of time shewn by a well regulated clock and a correct sun dial.

120. A true solar day is the time from the sun's leaving the meridian of any place, on any day, till it returns to the same meridian on the next day, viz. it is the time elapsed from 12 o'clock at noon, on any day, to 12 at noon, on the next day, as shewn by a correct sun dial.

121. A mean solar day is measured by equal motion, as by a clock or time-piece, and consists of twenty-four hours.

* Reduce 69° 20′ 45″ to time.
4

4 h. 37′ 23″ 00‴

† Reduce 1 h. 33′ 44″ to degrees.
10

	15 37 20
half,	7 48 40
	23° 26′ 00″

122. An astronomical day consists of twenty-four hours, being reckoned from noon to noon.

123. The Artificial day is the time elapsed between the sun's rising and setting, and is variable according to the different latitudes of places.

124. The civil day, like the astronomical day, consists of twenty-four hours, but begins differently in different nations.

125. The sidereal day is the interval of time from the apparent passage of any fixed star over the meridian, till it returns again; or it is the time which the earth takes to revolve once round its axis, and consists of twenty-three hours, fifty-six minutes, four seconds.

126. A solar or tropical year is the time the sun takes in passing through the ecliptic, from one tropic or equinox, till it returns to it again, and consists of three hundred and sixty-five days, five hours, forty-eight minutes, forty-eight seconds.

127. A sidereal year is the space of time which the sun takes in passing from one fixed star, till he returns to it again, and consists of three hundred and sixty-five days, six hours, nine minutes, and twelve seconds.

128. The sidereal year is twenty minutes, twenty-four seconds longer than the solar year, and the sun returns to the equinox every year before he returns to the same point of the heavens; consequently the equinoctial points have a retrograde motion.

129. The *precession* (or more properly the *recession*) of the equinoxes is a slow motion of the equinoctial points from east to west, contrary to the order of the signs.

130. The retrograde motion of the equinoctial points is about 50¼ seconds in a year, so that it would require 25,791 years for the equinoctial points to perform an entire revolution westward,

round the globe. This period the ancients called the Platonic or great year; and imagined that at its completion every thing would begin as at first, and all things come round in the same order as they had done before.

131. Positions of the sphere are three—right, parallel, and oblique.

132. A right sphere is that position of the earth in which the equator passes through the zenith and nadir, the poles being in the rational horizon.

133. A right sphere is so called because all the parallels of latitude cut the horizon at right angles, and the horizon divides them into two equal parts, making equal day and night. The inhabitants who have this position of the sphere, live at the equator.

134. A parallel sphere is the position of the earth when the rational horizon coincides with the equator, the poles being in the zenith and nadir.

135. A parallel sphere is so called, because all the parallels of latitude are parallel to the horizon, with which the equator coincides. The inhabitants who have this sphere, (if there be any such inhabitants,) live at the poles, and see the sun above their horizon for six months together.

136. An oblique sphere is the position which the earth has when the rational horizon cuts the equator obliquely. This sphere is common to all the inhabitants of the earth, who do not live exactly at the equator or the poles.

137. Climate is part of the surface of the earth, contained between two small circles parallel to the equator, and of such a breadth, that the longest day in the parallel nearest to the pole exceeds the parallel next to the equator, half an hour in the torrid and temperate zones, or one mouth in the frigid zones.

138. There are twenty-four climates between the equator and each polar circle, and six climates between each polar circle and its pole.*

139. A zone is a portion of the surface of the earth, contained between two small circles parallel to the equator. There are five zones—one torrid, two temperate, and two frigid zones.—[Fig. 2]

140. The torrid zone extends from the tropic of Cancer to the tropic of Capricorn, and is 46° 56″ broad. The equator is in the middle of this zone, from which each tropic is distant 23° 28′. This zone was thought by the ancients to be uninhabitable, because it is exposed continually to the direct rays of the sun.

141. The two temperate zones. The north temperate zone extends from the tropic of Cancer to the arctic circle, and the south temperate zone, from the tropic of Capricorn to the antarctic circle.—[Fig. 2.]

142. The temperate zones are each 43° 4′ broad, and were called temperate by the ancients, because, by meeting the sun's rays obliquely, they enjoy a moderate degree of heat.

143. The two frigid zones. The north frigid zone, or rather segment of a sphere, is bounded

* From this technical definition of climate, we must not infer that all places situated in the same parallel of latitude, have the same atmospherical temperature. For instance, in Canada, about the latitude of Paris and the south of England, the cold is so excessive, that the greatest rivers are frozen over from December to April, and the snow commonly lies from four to six feet deep; but the temperature of the atmosphere in the same latitudes, in France and Great Britain, is comparatively warm and mild. The Andes mountains, though part of them are situated in the torrid zone, are, at their summits, covered with snow, which cools the air of the adjacent countries. The heat on the western coast of Africa, after the wind has passed over the sandy desert, is almost suffocating; whilst the same wind, having passed over the Atlantic ocean, is cool and refreshing to the inhabitants of the Caribbean islands.

by the arctic circle. The north pole, which is situated in the middle of this zone, is 23° 28′ from the arctic circle.—[Fig. 2.]

144. The south frigid zone is bounded by the antarctic circle, distant 23° 28′ from the south pole, which is situated in the centre of this zone.

145. The ancients supposed the frigid zones uninhabited on account of the extreme cold which prevailed in them. They believed that the temperate zones were the only habitable parts of the earth.

146. Amphiscii are the inhabitants of the torrid zone, so called because they cast their shadows both north and south, at different times of the year; the sun being north of them at noon, when it has north declination, and then they cast their shadows south; when the sun has south declination, they cast their shadows north.

147. When the sun is vertical, or in the zenith, to the inhabitants of any place in the torrid zone, they have no shadow, and are called Ascii, or shadowless.

148. Heteroscii, is the name given to the inhabitants of the temperate zones, because they cast their shadows, at noon, only one way. Thus, the shadow of an inhabitant of the north temperate zone always falls to the north at noon, because the sun is then directly south; and an inhabitant of the south temperate zone casts his shadow south, because the sun is due north at that time.

149. Periscii are the people who inhabit the frigid zones, so called, because their shadows, during a revolution of the earth on its axis, are directed towards every point of the compass. In the frigid zones, the sun does not set during several revolutions of the earth upon its axis.

150. Antoeci are those who live in the same degree of Longitude, and in equal degrees of lat-

itude; but the one has north, and the other, south latitude. They have noon at the same time, but contrary seasons of the year; consequently the length of the day to the one is equal to the length of the night to the other. Those who live at the equator have no Antoeci.

151. Perioeci are those who live in the same latitude but in opposite longitudes. When it is noon with the one, it is midnight with the other. They have the same length of days and nights, and the same seasons of the year. The people at the poles have no Perioeci.

152. Antipodes are the inhabitants of the earth who live diametrically opposite to each other, and consequently walk feet to feet. Their latitudes, longitudes, seasons of the year, days, and nights, are all contrary to each other.

153. The crepusculum or twilight is that faint light which we perceive before the sun rises and after he sets. It is occasioned by the earth's atmosphere refracting the rays of light, and reflecting them from the particles thereof. The twilight is supposed to end in the evening, when the sun is 18° below the horizon, and to begin in the morning, or it is *day break*, when the sun is again within 18° of the horizon.

154. The twilight is shortest at the equator, and longest at the poles, where the sun is near two months before he retreats 18° below the horizon; and he is only two months more before he arrives at the same parallel of latitude.

155. Refraction. The earth is surrounded by a body of air, called the atmosphere, through which the rays of light come to the eye from all the heavenly bodies; and since these rays are emitted through a very *rare* medium, and fall obliquely upon the atmosphere, which is a dense medium, they are, by the laws of optics, refracted

in lines approaching nearer to a perpendicular, from the place of observation, (or nearer to the zenith) than they would be, were the medium removed. Hence all the heavenly bodies appear higher than they really are; and the nearer they are to the horizon, the greater the refraction or difference between their real and apparent altitudes will be.

156. Any fluid or substance, through which a ray of light can penetrate, is called a *medium*, as air, water, oil, glass, &c. The air near the earth is denser than in the higher regions of the atmosphere; and beyond the atmosphere, the rays of light are supposed to meet with little or no resistance.

157. The atmosphere extends to an unknown height; but if, as astronomers generally calculate, the sun begins to enlighten it in the morning, when he comes within 18° of the horizon of any place, the height of the atmosphere may be calculated to be nearly fifty miles. Its weight or pressure, upon a square inch of the earth's surface, is equal to about fifteen pounds avoirdupoise weight.

158. Refraction is variable according to the different densities of the air; hence it happens that we sometimes are able to see the tops of mountains, towers, or spires of churches, which are at other times invisible, though we stand in the same place. The density of the atmosphere decreases with its height.

159. When the sky is *clear*,* by the greater density of the atmosphere, we see the sun about

* The state of the atmosphere is often very improperly expressed by those who are unacquainted with its nature, who, when their spirits are depressed, ascribe the effect to the heaviness of the air; whereas, on the contrary, it is produced by its rarity or lightness; which, rendering its impressions weaker on our bodies, and not sufficient to counteract the spring of the air within them, the blood vessels and nerves become relaxed; but when the air is more dense,

ten minutes before he transits or actually rises above the horizon; but when it is cloudy, not above six minutes—the time differing according to the density; which difference, from the most rare state, is found to be about four minutes. We also see the image of the moon about two minutes before she actually transits our horizon, in the densest state of the atmosphere.

160. The sun's meridian altitude, on the longest day, decreases from the tropic of cancer to the north pole; and in the torrid zone, when the sun is vertical, there is no refraction; hence, the refraction is the least in the torrid zone, and the greatest at the poles.*

161. Angle of position, between two places on the terrestrial globe, is an angle at the zenith of one of the places, formed by the brass meridian and the quadrant of altitude passing through the other place, and is measured on the horizon.

162. Rhumbs are the divisions of the horizon into thirty-two parts, called the points of the compass. A rhumb line is a spiral curve, drawn, or supposed to be drawn upon the earth, so as to cut each meridian at the same angle, called the proper angle of the rhumb. If this line be continued, it will never return into itself, so as to form a circle, except it happen to be due east and west, or due north and south; and it can never be a right line upon any map, except the meridians be parallel to each other, as on Mercator's and the plane chart.

as is always the case when we see the vapours and clouds buoyed up by it, its weight and elasticity, balancing the internal air, braces up the whole system and makes us feel light and sprightly.—Mrs. Bryan.

* Varenius, in his geography, speaking of the wintering of the Dutch in Nova Zembla, latitude 76° north, A. D. 1596, says, they saw the sun, in the year 1597, six days sooner than they would have seen it had there been no refraction.

163. Analemma. What is called the analemma, on the globe, is a narrow slip of paper, the length of which is equal to the breadth of the torrid zone. It is pasted on some vacant place on the globe, in the torrid zone, and is divided into months and days of months, correspondent to the sun's declination for every day in the year. It is divided into two parts; the right hand part begins at the winter solstice, or December 21st, and is reckoned upwards towards the summer solstice, or June 21st, where the left hand part begins, which is reckoned downwards, in a similar manner, towards the winter solstice.

164. The figure of the earth, as composed of land and water, is nearly spherical. The only certain conclusion that can be drawn from the works of the several gentlemen who have been employed to measure the earth, is that "the earth is something more flat at the poles, than at the equator." The equinoctial diameter of the earth is about thirty-four miles longer than the polar diameter.

165. What the earth loses of its sphericity by mountains and vallies, is very inconsiderable. Chimboraco, one of the Andes mountains, the highest in the world, is about twenty thousand six hundred and eight feet, or nearly four miles high, which elevation, if represented on an eighteen inch globe, would be less in height than a grain of sand.

166. The celestial globe is an artificial representation of the heavens, on which the stars are laid down in their natural situations. The diurnal motion of this globe is from east to west, and represents the apparent diurnal motion of the sun, moon, and stars. In using this globe, the student is supposed to be situated in the centre of it, and viewing the stars in the concave surface.—[Fig. 3.]

167. The ecliptic is a great circle in which the sun makes his apparent progress among the fixed stars.*—[Vide Def. 61.]

168. The zodiac on the celestial globe is a space which extends about eight degrees on each side of the ecliptic, like a belt or girdle, within which the motions of all the planets (except the newly discovered planets or Asteroids) are performed.—[Fig. 3.]

169. Latitude of a star or planet, on the celestial globe, is its distance from the ecliptic, northward or southward, counted towards the poles of the ecliptic, on the quadrant of altitude.—[Fig. 3.]

170. The greatest latitude a star can have is 90°, and the greatest latitude of a planet is nearly 8°. The Asteroids, Ceres, Pallas, and Juno, do not appear to be confined within these limits.

171. Longitude of a star or planet is reckoned on the ecliptic from the point Aries, eastward, round the globe. The longitude of the sun is continually changing, and is what is called the sun's place on the terrestrial globe.

172. Almacanters or parallels of altitude are imaginary circles parallel to the horizon, and serve to shew the height of the sun, moon, and stars. These circles are not drawn on the globe, but they may be described for any latitude, by the quadrant of altitude.

173. Parallels of celestial latitude are small circles drawn on the celestial globe, parallel to the ecliptic.—[Fig. 3.]

174. Parallels of declination are small circles, drawn parallel to the equinoctial, on the celestial

* The sun's apparent diurnal path is either in the equinoctial, or in lines nearly parallel to it, and his apparent annual path may be traced in the heavens, by observing what particular constellation in the zodiac is on the meridian at midnight; the opposite constellation will shew, very nearly, the sun's place at noon, on the same day.

globe, and are similar to the parallels of latitude on the terrestrial globe.

175. The colures are two great circles passing through the poles of the world; one of them passes through the equinoctial points, Aries and Libra; the other through the solstitial points, Cancer and Capricorn: hence, they are called the equinoctial and solstitial colures. They divide the ecliptic into four equal parts, and mark the four seasons of the year.—[Fig. 7.]

176. Azimuth or vertical circles are imaginary great circles passing through the zenith and nadir, cutting the horizon at right angles. The altitudes of the heavenly bodies are measured on these circles, which may be represented by screwing the quadrant of altitude on the zenith of any place, and making the other end move along the wooden horizon of the globe.

177. The prime vertical is that azimuth circle which passes through the east and west points of the horizon, and is always at right angles with the brass meridian, which may be considered as another vertical circle, passing through the north and south points of the horizon.

178. Parallax is the difference between the true altitude of the sun, moon, or a star, if it were observed at the *centre* of the earth, and the apparent altitude observed at the same instant by a spectator at any point on the *surface* of the earth Parallax makes objects appear lower than they really are; it is greatest at the horizon, and decreases from thence to the zenith, where it is nothing.

179. The altitude of any object in the heavens, is an arch of a vertical circle, contained between the centre of the object and the horizon. When the object is on the meridian, this arch is called the meridian altitude.

180. The zenith distance of any celestial object is the arch of a vertical circle, contained between the centre of that object and the zenith; or it is what the altitude of the object wants of 90°. When the object is on the meridian, this arch is called the meridian zenith distance.

181. The polar distance of any celestial object is an arch of a meridian contained between the centre of that object, and the pole of the equinoctial.

182. The amplitude of any object in the heavens is an arch of the horizon, contained between the centre of the object when rising or setting, and the east or west points of the horizon. The sun never rises exactly in the east nor sets exactly in the west, except at the time of the equinoxes.

183. The azimuth of any object in the heavens is an arch of the horizon, contained between a vertical circle, passing through the centre of the object and the north or south points of the horizon. The azimuth of the sun, at any particular hour, is used at sea for finding the variation of the compass.

184. Hour or horary circles are the same as meridians. They are drawn through every 15°* of the equator, each answering to an hour; consequently, every degree of longitude answers to four minutes of time, every half degree to two minutes, and every quarter of a degree to one minute. On the globes, these circles are supplied by the brass meridian, the hour circle, and its index.

185. The six o'clock hour line. As the meridian of any place, with respect to the sun, is called the 12 o'clock hour circle; so that great circle, passing through the poles, which is 90° distant from it on the equator, is called by astronomers

* On Cary's globes the meridians are drawn through every 10°.

the 6 o'clock hour line. The sun and stars are on the eastern half of this line, six hours before they come to the meridian; and on the western half, six hours after they have passed the meridian.

186. The culminating point of a star or planet, is that point of its orbit which, on any given day, is the most elevated. Hence a star or planet is said to culminate, when it comes to the meridian of any place; for then its altitude, at that place, is greatest.

187. The right ascension of the sun or a star, is that degree of the equinoctial which rises with the sun or a star, in a right sphere, and is reckoned from the equinoctial point Aries, eastward, round the globe.

188. Oblique ascension of the sun or a star, is that degree of the equinoctial which rises with the sun or a star, in an oblique sphere, and is likewise counted eastward from the point Aries, round the globe.

189. Oblique decension of the sun or a star, is that degree of the equinoctial which sets with the sun or a star, in an oblique sphere.

190. Ascensional or Descensional difference, is the difference between the right and oblique ascension, or the difference between the right and oblique descension, and with respect to the sun, it is the time he rises before 6 in the summer, or sets before 6 in the winter.

191. The fixed stars are so called, because they have usually been observed to keep the same distance with respect to each other.

192. The fixed stars have an apparent motion from east to west, in circles parallel to the equinoctial, arising from the revolution of the earth from west to east; and on account of the precession of the equinoxes, their longitudes increase

about 50¼ seconds in a year; this likewise causes a variation in their declinations and right ascensions: their latitudes are also subject to a small variation.

193. The precession of the equinoctial points has occasioned an apparent advance of the fixed stars, in their longitude, of about 50¼ seconds per year; from whence it follows, that since the time of Ptolemy, in the infant state of astronomy, the zodiacal figures or constellations have moved forwards about one whole sign, as shewn on the celestial globe, the constellation Aries being situated in that part of the ecliptic named Taurus, Taurus in Gemini, &c. Hence the stars that used to rise and set at particular seasons of the year in the times of Hesiod, Eudoxus, Virgil, Pliny, &c. at present, will have a manifest difference in respect to time. In the time of Hipparchus, who made his observations between one hundred and sixty, and one hundred and thirty-five years before Christ, the equinoctial colure is supposed to have passed through the middle of the constellation Aries.

194. The poetical rising and setting of the stars, so called because they are noticed by the ancient poets, who referred the rising and setting of the stars to the sun. When a star rose with the sun, or set when the sun rose, it was said to rise and set *cosmically*; when a star rose at sun-setting, or set with the sun, it was said to rise and set *achronically*; when a star first became visible in the morning, after having been so near the sun as to be hid by the splendour of his beams, it was said to rise *heliacally*; and when a star first became invisible in the evening, on account of its nearness to the sun, it was said to set *heliacally*.

195. A constellation is an assemblage of stars, on the surface of the celestial globe, circumscribed

by the outlines of some assumed figure, as a ram, a dragon, a bear, &c. This division of the stars into constellations is necessary, in order to direct the eye to any part of the heavens, where any particular star is placed.

196. The following tables contain all the constellations on the new British globes. The northern are, in number, 34; the southern, 47; the zodiacal, 12; amounting in the whole to 93 constellations. The largest stars are called stars of the first magnitude; those of the next size are called stars of the second magnitude; and they are thus distinguished numerically, down to the sixth. Stars of the sixth magnitude are the smallest that can be seen by the naked eye. All stars that cannot be seen without the assistance of the telescope, are called telescopical stars.

CONSTELLATIONS IN THE ZODIAC.

	Constellations.	*No. of stars.*	*Names of principal stars.*
1	Aries, the ram,	66	Arietis, 2.
2	Taurus, the bull,	141	Aldabaran, 1. The Pleiades, The Hyades.
3	Gemini, the twins,	85	Castor 1 Pollux 2
4	Cancer, the crab,	83	
5	Leo, the Lion,	95	Regulus, 1.
6	Virgo, the virgin,	110	Spica, 1. Vindemiatrix, 2.
7	Libra, the balance,	51	
8	Scorpio, the scorpion,	44	Antares, 1.
9	Sagittarius, the archer,	69	
10	Capricornus, the goat,	51	
11	Aquarius, the water-bearer,	108	Scheat, 3.
12	Pisces, the fishes,	113	

NORTHERN CONSTELLATIONS.

	Constellations.	*No. of stars.*	*Names of principal stars.*
1	Mons Maenalus,	11	
2	Serpens,	64	
3	Serpentarius,	74	Ras Alhagus
4	Taurus Poniatowski,	7	
5	Scutum Sobieski,	8	
6	Aquila, Antinous,	71	Altair, 1.
7	Equulus,	10	
8	Leo Minor,	53	Deneb, 2.
9	Coma Berenices,	43	
10	Asterion and Chara, or Canes Venatici,	25	
11	Boötes,	54	Arcturus, 1. Mirach, 3.
12	Corona Borealis,	21	Alphacca, 2.
13	Hercules, Cerberus,	113	Ras Algethi, 3. in hd. of Herc.
14	Lyra,	21	Vega, 1.
15	Vulpecula and Anser,	35	
16	Sagitta,	18	
17	Delphinus,	18	
18	Pegasus,	89	Markab, 2. Scheat, 2.
19	Andromeda,	66	Mirach, 2. Almaach, 2.
20	Triangulum,	11	
21	Triangulum minus,	5	
22	Musca,	6	
23	Ursa minor,	24	Pole star, 2.
24	Ursa major,	87	Dubhe, 2. Alioth, 2. Benetnach, 2.
25	Cor Caroli,	3	
26	Draco,	80	Rastaban, 2.
27	Cygnus,	81	Deneb Adige, 1
28	Lacerta,	16	
29	Cepheus,	35	Alderamin, 3.
30	Cassiopeia,	55	Schedar, 3.
31	Perseus, Caput Medusæ,	59	Algenib, 2. Algol, 2.
32	Camelopardalus,	58	
33	Auriga,	66	Capella, 1.
34	Lynx,	44	

SOUTHERN CONSTELLATIONS.

	Constellations.	*No. of stars.*	*Names of principal stars.*
1	Cetus,	97	Menkar, 2.
2	Eridanus,	84	Acherner, 1.
3	Orion,	78	Bellatrix, 2. Betelguese, 1. Rigel, 1.
4	Monoceros,	31	
5	Canis minor,	14	Procyon, 1.
6	Hydra,	60	Cor Hydra, 1.
7	Sextans,	41	
8	Microscopium,	10	
9	Piscis Australis,	24	Fomalhault, 1,
10	Officina Sculptoria,	12	
11	Fornax Chymica,	14	
12	Brandenburgium Sc.	3	
13	Lepus,	19	
14	Columba Noachi,	10	
15	Canis major,	31	Sirius, 1.
16	Pyxis Nautica,	4	
17	Machina Pneumatica,	3	
18	Crater,	31	Alkes, 3.
19	Corvus,	9	Algorab, 3.
20	Centaurus,	35	
21	Lupus,	24	
22	Quadra Euclidis,	12	
23	Circinus,	4	
24	Triangulum Australe,	5	
25	Crux,	5	
26	Musca Australis vel apis,	4	
27	Chamœleon,	10	
28	Ara,	9	
29	Telescopium,	9	
30	Corona Australis,	12	
31	Indus,	12	
32	Grus,	13	
33	Pavo,	14	
34	Avis Indica,	11	
35	Octans Hadleianus,	43	
36	Phœnix,	13	
37	Horologium,	12	
38	Reticulum Rhomboidum,	10	
39	Hydrus,	10	
40	Touchan,	9	

	Constellations.	No. of stars.	Names of principal stars.
41	Mons Mensæ,	30	
42	Cela Sculptoria,	16	
43	Equuleus Pictorius,	8	
44	Dorado or Xiphias,	6	
45	Argo Navis,	64	Canopus, 1.
46	Piscis Volans,	8	
47	Robur Caroli,	12	

197. The magnitude of the fixed stars will probably forever remain unknown; all the knowledge of their size that we can have any reason to expect, is an approximation founded on conjecture. It has been concluded from a comparison of the light afforded by a fixed star, and that of the sun, that the stars do not materially differ, in magnitude, from the sun. The different apparent magnitudes of the sun is supposed to arise from their different distances; for the fixed stars are not placed in a concave hemisphere, as they appear in the heavens, or in a convex surface, as they are represented on a celestial globe.

198. The distances of the fixed stars are so immensely great, that it is impossible for them to shine by the light of the sun reflected from their surfaces; they must therefore be of the same nature with the sun, and, like him, shine with their own light, being suns to systems of worlds, to us invisible. Sirius, the nearest of the fixed stars, is two billions, two hundred thousand millions of miles from our earth. A cannon ball discharged from the earth, moving at the rate of 480 miles an hour, would not arrive at it in a less time than 700,000 years.

199. The number of fixed stars is beyond all human powers of computation. Those which may be seen by the naked eye, however, are about 3000; comprehending all the stars from the first

to the sixth magnitude. But a good telescope, directed almost indifferently to any point in the heavens, discovers multitudes of stars, which, without it, would be invisible.

200. The Galaxy, Via lactea, or Milky way, is a whitish luminous tract which seems to encompass the heavens like a gridle, of a considerable, though unequal breadth, varying from 4 to 20°. It is composed of an infinite number of small stars, which, by their joint light, occasion that confused whiteness which we perceive in a clear night.

201. The milky way may be traced on the celestial globe, beginning at Cygnus, through Cepheus, Cassiopeia, Perseus, Auriga, Orion's club, the feet of Gemini, part of Monoceros, Argo Navis, Robur Caroli, Crux, the feet of the Centaur, Circinus, Quadra Euclidis, and Ara—here it is divided into two parts; the eastern branch passes through the tail of Scorpio, the bow of Sagittarius, Scutum Sobieski, the feet of Antinous, Aquila, Sagitta, and Vulpecula; the western branch passes through the upper part of the tail of Scorpio, the right side of Serpentarius, Taurus Poniatowski, the Goose, and the neck of Cygnus, in the body of which constellation, it meets and unites with the eastern branch.

202. Nebulous, or Cloudy, is a term applied to certain fixed stars, smaller than those of the sixth magnitude, which only shew a dim, hazy light, like little specks or clouds. It may be further remarked, that the milky way is a continued assemblage of Nebulæ. In some of the spaces termed Nebulous, no stars appear.

203. Magellanic clouds are whitish appearances like clouds, seen in the heavens towards the south pole, and having the same apparent motion as the stars. They are three in number, two of

them near each other. The largest lies at a considerable distance from the south pole, but the other two are not many degrees more remote from it than the nearest conspicuous star, that is, about 11°. They are now supposed to be Nebulæ of small stars, like the milky way.

204. Bayer's characters. John Bayer, of Augsburg, in Swabia, published, in 1603, an excellent work, entitled Uranometria, being a celestial atlas of all the constellations, with the useful invention of denoting the stars in every constellation, by the letters of the Greek and Roman alphabets; setting the first Greek letter (α) to the principal star in each constellation, (β) to the second, (γ) to the third, and so on; and when the Greek alphabet was finished, he began with *a*, *b*, *c*, &c. of the Roman. This useful method has been followed by all succeeding astronomers, who have farther enlarged it, by adding the numbers 1, 2, 3, &c. when any constellation contains more stars than can be marked by the two alphabets. The figures are, however, sometimes placed over the Greek letter, especially where double stars occur; for, though many stars may appear single to the naked eye, yet, when viewed through a telescope of considerable magnifying powers, they appear double, triple, &c. Thus, in Dr. Zach's Tabulæ motuum Solis, we meet with (*f*) Tauri, (β) Tauri, (γ) Tauri, (δ^1) Tauri, (δ^2) Tauri, &c.

205. As the Greek characters so frequently occur in catalogues of stars, and on the celestial globe, the Greek alphabet is here inserted, for the use of those who are unacquainted with the letters. The capitals are seldom used by astronomers, but are here given for the sake of regularity.

Figure.	Name.		Power or sound.
Α α	Ἄλφα	Alpha	a
Β β ϐ	Βῆτα	Beta	b
Γ γ	Γάμμα	Gamma	g
Δ δ	Δέλτα	Delta	d
Ε ε	Ἐψιλὸν	Epsilon	e short
Ζ ζ ζ	Ζῆτα	Zeta	z
Η η	Ἦτα	Eta	e long
Θ ϑ θ	Θῆτα	Theta	th
Ι ι	Ἰῶτα	Iota	i
Κ κ	Κάππα	Kappa	k c
Λ λ	Λάμβδα	Lambda	l
Μ μ	Μῦ	Mu	m
Ν ν	Νῦ	Nu	n
Ξ ξ	Ξῖ	Xi	x
Ο ο	Ὀμικρὸν	Omicron	o short
Π ϖ π	Πῖ	Pi	p
Ρ ϱ ρ	Ῥῶ	Rho	r
Σ ϲ σ ς	Σῖγμα	Sigma	s
Τ τ	Ταῦ	Tau	t
Υ υ	Ὑψιλὸν	Upsilon	u
Φ φ	Φῖ	Phi	ph
Χ χ	Χῖ	Chi	ch
Ψ ψ	Ψῖ	Psi	ps
Ω ω	Ὠμέγα	Omega	o long

206. Planets are opaque bodies, similar to our earth, which move round the sun in certain periods of time. They shine not by their own light, but by the reflection of the light which they receive from the sun. The planets are distinguished into primary and secondary.

207. The primary planets regard the sun as the centre of their motion. There are eleven primary planets, distinguished by the following characters and names: ☿ Mercury, ♀ Venus, ⊕ the Earth, ♂ Mars, Ceres, Pallas, Juno, Vesta, ♃ Jupiter, ♄ Saturn, ♅ Georgium Sidus or Herschel.

208. Since the 1st of January, 1801, four new planetary bodies have been discovered, between the orbits of Mars and Jupiter, to which the names Ceres, Pallas, Juno, and Vesta have been given. They are apparently at such equal distances from the sun, that it is not yet decided with certainty, which of them is the nearest or the most remote. Their orbits are not confined within the limits of the zodiac. Neither of them is visible to the naked eye, or appears, through a telescope, larger than a star of the fifth magnitude. They are generally called Asteroids.

209. The secondary planets, satellites or moons, regard the primary planets as their centres of motion; thus, the moon revolves about the earth, the satellites of Jupiter move round that planet, &c. There are eighteen secondary planets. The Earth has one satellite, Jupiter four, Saturn seven, and the Georgium Sidus six satellites.

210. The orbit of a planet is the imaginary path which it describes round the sun. The earth's orbit is represented by the ecliptic.

211. Nodes are the two opposite points, where the orbit of a planet seems to intersect the ecliptic. The node in which the planet appears to ascend from the south to the north side of the ecliptic, is called the ascending Node, and is marked thus, ☊; and the opposite point, where the planet appears to descend, from the north to the south side of the ecliptic, is called the descending Node, and is marked thus, ☋.

212. *Aspect* of the stars and planets is their situation with respect to each other. There are five aspects, viz. ☌ *Conjunction*, when they are in the same sign and degree; ✱ *Sextile*, when they are two signs or a sixth part of a circle distant; □ *Quartile*, when they are three signs, or a fourth part of a circle from each other; △ *Trine*, when

they are four signs or a third part of a circle from each other; ☍ *Opposition*, when they are six signs or half a circle apart.

213. The conjunction and opposition (particularly of the moon) are called the *Syzygies;* and the Quartile aspect, the *Quadratures.*

214. *Direct.* A planet's motion is said to be *direct*, when it appears, to an observer on the earth, to go forward in the zodiac, according to the order of the signs.

215. *Stationary.* A planet is said to be stationary, when, to an observer on the earth, it appears for some time in the same point of the heavens.

216. *Retrograde.* A planet is said to be retrograde, when it apparently goes backward, or contrary to the order of the signs.

217. *Digit.* The twelfth part of the sun's or moon's apparent diameter.

218. *Disc.* The face of the sun or moon, such as it appears to a spectator on the earth; for though the sun and moon be really spherical bodies, they appear to be circular planes.

219. *Geocentric* latitudes and longitudes of the planets, are their latitudes and longitudes, as seen from the earth.

220. *Heliocentric* latitudes and longitudes of the planets, are their latitudes and longitudes, as they would appear to a spectator situated in the sun.

221. *Apogee*, or *Apogeum*, is that point in the orbit of a planet, the moon, &c. which is farthest from the earth.

222. *Perigee*, or *Perigeum*, is that point in the orbit of a planet, the moon, &c. which is nearest to the earth.

223. *Aphelion*, or *Aphelium*, is that point in the orbit of the earth, or of any other planet, which

is farthest from the sun. This point is called the higher Apsis.

224. *Perihèlion*, or *Perihelium*, is that point in the orbit of the earth, or of any other planet, which is nearest to the sun. This point is called the lower Apsis.

225. *Line of the Apsides*, is a straight line joining the higher and lower apsis of a planet, viz. a line joining the Aphelium and Perihelium.

226. *Eccentricity* of the orbit of any planet, is the distance between the sun, and the centre of the planet's orbit.

227. *Occultation* is the obscuration, or hiding from our sight, of any star or planet, by the interposition of the body of the moon, or any other planet.

228. *Transit* is the apparent passage of any planet over the face of the sun, or over the face of any other planet. Mercury and Venus, in their transits over the sun's disc, appear like dark specks. *Transit* is also the passage of the sun, moon, or any other planet, over the meridian, horizon, or some other line or circle of the heavens.

229. *Eclipse of the sun* is an occultation of part of the disc of the sun, occasioned by an interposition of the moon, between the earth and the sun; consequently, all eclipses of the sun happen at the time of the new moon. Sometimes the whole disc is hidden, and then the eclipse is said to be total.

230. *Eclipse of the moon* is a privation of the light of the moon, occasioned by the interposition of the earth, between the sun and the moon; consequently, all eclipses of the moon happen when she is full.

231. *Elongation* of a planet is the angle formed by two lines drawn from the earth, the one to the sun and the other to the planet. It is the apparent distance of a planet from the sun, as seen from the earth.

232. *Diurnal arch* is the arch described by the sun, moon, or stars, from their rising to their setting. The sun's semi-diurnal arch is that which he describes in half the length of a day.

233. *Nocturnal arch* is the arch described by the sun, moon, and stars, from their setting to their rising.

234. *Aberration* is an apparent motion of the celestial bodies, occasioned by the earth's annual motion in its orbit, combined with the progressive motion of light.

235. *Centripetal force* is that force with which a moving body is perpetually urged towards a centre, and made to revolve in a curve, instead of proceeding in a right line; for all motion is naturally rectilinear. Centripetal force, attraction, and gravitation are terms of the same import.

236. *Centrifugal force* is that force with which a body, revolving about a centre, or about another body, endeavours to recede from that centre or body. There are two kinds of centrifugal force, viz. that which is given to bodies, moving round another body as a centre, usually called the *projectile force;* and that which bodies acquire by revolving upon their own axes. Thus, for example, the annual orbit of the earth round the sun, is regulated by the action of the centripetal and projectile forces; and the diurnal rotation of the earth on its axis, gives to all its parts a centrifugal force, proportional to its velocity.

237. The orbit of the earth, and of the other planets, is not a circle, but is of an elliptical form, having the sun in one of its foci*—nor is the mo-

* To understand the true meaning of the term *foci*, a knowledge of Geometry and Conic Sections is necessary. It will be sufficient, in this place, for the young pupil to know, that if a thread, with its ends united, be laid on a piece of paper, and two pins be fixed at any distance on a line, within the thread,—

tion of the earth in its orbit uniform; for it is about eight days longer in its aphelion, than in its perihelion; yet its motion is regulated by a certain immutable law, from which it never deviates; which is, that a line drawn from the centre of the sun to the centre of the earth, being carried about with an angular motion, describes an elliptical area, proportional to the time in which that area is described, viz. if the times in which the earth moves from A to E*, from E to D, and from D to B, be equal, then the areas or spaces A S E, E S D, and D S B, will all be equal. The motion of the earth is sometimes quicker, and sometimes slower in moving through equal parts of its orbit: for when the earth is at A, in winter, the sun attracts it more strongly, and therefore the motion is quicker than any where else; when it is at B, in the summer, it is least affected by the sun's attraction, and, consequently, the motion is there slower than in any part of its orbit; for the power of gravity decreases as the squares of the distances increase: besides, it is evident from the construction of the figures, that, if the space A S E be described in the same time with the space B S D, the arch A E will be greater than the arch B D. All the other planets move in a similar manner, in elliptical orbits, and their motions, times, &c. are regulated by the same law which regulates those of the earth.

238. Systems—the Ptolemaic. In the Ptolemaic system, the earth is supposed to be at rest in the centre of the universe, while the heavens are considered as revolving about it, from east to

then, if he take a pencil, and move it round the pins, so as to keep the thread fully stretched, an ellipsis will be formed, of which, the points where the pins were fixed, will be the *foci*.

* See Fig. 4.

west, in twenty-four hours, and carrying with them all the stars and planets.

239. The Tychonic system was invented and taught by Tycho Brahe, a Dane. It supposes that the earth is fixed in the centre of the universe, or firmament of stars; and that all the stars and planets revolve around the earth in twenty-four hours. But it differs from the Ptolemaic system, as it not only allows a monthly motion to the moon round the earth, and that of the satellites round Jupiter and Saturn, in their proper periods: but the sun is, in this system, considered as the centre of the primary planets, which, in their orbits, are carried round the sun in their respective years, as the sun revolves round the earth in a solar year; and all these planets, with the sun, are supposed to move round the earth in twenty-four hours. This hypothesis, embarrassed and perplexed with so many obviously contradictory suppositions, gained but few advocates.

240. The Cartesian system was invented by René Descartes, a learned Frenchman, who flourished in the seventeenth century. He maintained the elements of all matter to be indivisible atoms. He made a small improvement on the systems of the ancients, by alleging that these atoms are not all alike, or of the same magnitude. He attributed to each atom a particular motion on its own axis, and to the whole universe of atoms, a general motion round a common centre, as in a vortex or whirlpool. He asserted that the most rare particles of matter collected in the middle of the system and formed the sun. In addition to this general and common vortex, he assigned to each primary planet and its satellite, an appropriate and subordinate vortex, which occasioned the revolution on its own axis. "In short" says an ingenious investigator of this system, "the word *vortex*,

in the hand of Descartes, was a key to unlock all the secrets of nature." But this hypothesis has long been condemned as unphilosophical, false, and visionary; and has, with the inventions of Ptolemy and Tycho, given place to the Copernican or true Solar system.*

GEOGRAPHICAL THEOREMS.

241. The latitude of any place is equal to the elevation of the polar star, (nearly) above the horizon, and the elevation of the equator above the horizon is equal to the complement of latitude, or what the latitude wants of 90°.

242. All places under the equinoctial, or on the equator, have no latitude, and all places situated on the first meridian have no longitude; consequently, that particular point on the globe, where the first meridian intersects the equator, has neither latitude nor longitude.

243. The latitudes of places increase, as their distances, from the equator, increase. The greatest latitude a place can have is 90°.

244. The longitudes of places increase, as their distances, from the first meridian, increase—reckoned on the equator. The greatest longitude a place can have is 180°—being half the circumference of the globe at that place: hence, no two places can be at a greater distance from each other than 180°.

245. The sensible horizon of any place changes as often as we change the place itself.

246. All countries upon the face of the earth, in respect to time, equally enjoy the light of the sun, and are equally deprived of the benefit of it;

* See page 58.

that is, every inhabitant of the earth has the sun above his horizon for six months, and below his horizon for the same length of time.*

247. In all places of the earth, except exactly under the poles, the days and nights are of an equal length, viz. twelve hours each—when the sun has no declination; that is, on the 21st of March, and on the 23d of September.

248. In all places situated on the equator, the days and nights are always equal, notwithstanding the alteration of the sun's declination from north to south, or from south to north.

249. In all places, except those upon the equator, or at the two poles, the days and nights are never equal, but when the sun enters the signs of Aries and Libra, on the 21st of March and the 23d of September.

250. In all places lying under the same parallel of latitude, the days and nights, at any particular time, are always equal to each other.

* This, though nearly true, is not exactly so. The refraction in high latitudes is very considerable, and near the poles, the sun will be seen for several days before he transits the horizon; and he will, for the same reason, be seen for several days after he has descended below the horizon. The inhabitants of the poles, if any, enjoy a very great degree of twilight; the sun being nearly two months before he retreats 18° below the horizon, or to the point where his rays are first admitted into the atmosphere; and he is only two months more before he arrives at the same parallel of latitude; and particularly near the north pole, the light of the moon is greatly increased by the reflection of the snow and the brightness of the Aurora Borealis; the sun is likewise about seven days longer in passing through the northern than the southern signs; that is, from the vernal equinox, which happens on the 21st of March, to the autumnal equinox, which falls on the 23d of September, being the summer half year to the inhabitants of north latitude, is one hundred and eighty-six days: the winter half year is therefore only one hundred and seventy-nine days. The inhabitants near the north pole have, consequently, more light in the course of a year, than any other inhabitants on the surface of the globe.

251. The increase of the longest days from the equator, northward or southward, does not bear any certain ratio to the increase of latitude; if the longest days increase equally, the latitudes increase unequally. This is evident from the table of climates.

252. To all places in the torrid zone, the morning and evening twilight are the shortest; to all places in the frigid zones, the longest; and to all places in the temperate zones, a medium between the other two.

253. To all places lying within the torrid zone, the sun is vertical twice a year; to those under each tropic, once; but to those in the temperate and frigid zones, it is never vertical.

254. At all places in the frigid zones, the sun appears every year, without setting for a certain number of days, and disappears for nearly the same space of time: and the nearer the place is to the pole, the longer the sun continues without setting, viz. the length of the longest days and nights increases, the nearer the place is to the pole.

255. Between the end of the longest day, and the beginning of the longest night, in the frigid zone, and between the end of the longest night, and the beginning of the longest day, the sun rises and sets as at other places on the earth.

256. At all places situated under the arctic or antarctic circles, the sun, when he has 23° 28′ declination, appears for twenty-four hours without setting; but rises and sets at all other times of the year.

257. At all places between the equator and the north pole, the longest day and the shortest night are when the sun has 23° 28′, the greatest northern declination; and the shortest day and the longest night are when the sun has an equal degree of south declination. This theorem, if the

terms are reversed, is applicable to the days and nights in the southern hemisphere.

258. At all places situated on the equator, the shadow of an object at noon, placed perpendicularly to the horizon, falls towards the north during one half of the year, and towards the south, during the other half; except when the sun is in the equinoctial points, when no shadow is projected either way.

259. The nearer any place is to the torrid zone, the shorter the meridian shadow of objects will be. When the sun's altitude is 45°, the shadow of any perpendicular object is equal to its height.

260. The farther any place, situated in the torrid or temperate zones, is from the equator, the greater will be the sun's rising and setting amplitude.

261. All places situated under the same meridian, so far as the globe is enlightened, have noon at the same time.

262. If a ship set out from any port, and sail round the world, eastward, to the same port again, the people in the ship, in reckoning their time, will gain one complete day at their return, or count one day more than those who reside at the same port. If they sail westward, they will lose or reckon one day less.

263. To illustrate this, suppose the person who travels westward should keep pace with the sun, it is evident he would have continual day during his tour round the earth; but the people who remained at the place he departed from have had night in the same time, consequently, they reckon a day more than he does.

264. Hence, if two ships should set out at the same time, from any port, and sail round the globe, the one eastward and the other westwarrd, so as to meet at the same port, on any day whatever,

they will differ two days in their reckoning, at their return. If they sail twice round, they will differ four days; if thrice, six days, &c.

265. But if two ships should set out at the same time, from any port, and sail round the world, northward or southward, so as to meet at the same port, on any day whatever, they will not differ a moment in their time, nor from those who reside at the port.

BRIEF ACCOUNT OF THE SOLAR SYSTEM.

266. The solar system is so called, because the sun is supposed to be in a certain point, termed the centre of the system, having all the planets revolving around it at different distances, and in different periods of time—this is likewise called the Copernican system, from Nicholas Copernicus, a native of Thorn, in Prussia, and is the Pythagorean system revived and established.*

267. The sun is situated near the centre of the orbits of all the planets, and revolves on its axis in twenty-five days, fourteen hours, eight minutes. The sun is likewise agitated by a small motion round the centre of gravity of the Solar system, occasioned by the various attractions of the surrounding planets.

* The great ancient Philosopher, Pythagoras, was born about five hundred and ninety years before Christ. His father's principal residence was at Samos; but, being a travelling merchant, his son Pythagoras was born at Sidon, in Syria. He discovered and maintained the true system of the world, which places the sun in the centre, and makes all the planets revolve around him. This system, revived by Corpernicus and established by Galileo, Newton, and other learned modern sages, is now universally received as true, since it is the only one that can be brought to bear the test of mathematical analysis and demonstration.

268. As the sun revolves on an axis, his figure is supposed to be not exactly in the form of a globe, but a little flattened at the poles. His axis makes an angle of about 8°, with a perpendicular to the plane* of the earth's orbit.

269. As the sun's apparent diameter is longer in December than in June, it follows, that our earth is nearer to it in winter than in summer; for the apparent magnitude of a distant body diminishes as the distance increases. This circumstance also proves that the orbit of the earth is elliptical, the sun being in one of the foci.

270. The mean apparent diameter of the sun is 32′ 2″; hence, taking the distance of the earth from the sun to be ninety-five millions of miles, its real diameter will be eight hundred and eighty-three thousand miles. The sun is more than a million times larger than the earth.

271. The earth is farther from the sun in summer than in winter. To the question why our winters are colder than our summers, it may be answered, that our summer is hotter than our winter, first, on account of the greater height to which the sun rises above our horizon, in the summer; secondly, the greater length of the days. The sun is much higher at noon, in the northern hemisphere, than in winter; and, consequently, as his rays are less oblique, than in winter, more of them will fall on the surface of the earth. In the summer, the days are very long and the nights very short; therefore the earth and air are more heated in the day, than they are cooled in the night; and, on this account, the heat will keep increasing in the summer; and, in winter, when,

* Plane.—This term denotes a flat surface, lying evenly between its bounding lines.—Euclid. The sphere is wholly explained by planes conceived to cut the celestial bodies, and to fill the areas, or circumferences of their orbits.

during the long nights, the earth and air are more cooled in the night, than they are heated in the day, the cold will proportionably increase.

272. The solar system consists of eleven primary planets, eighteen secondary planets, satellites, or moons, and a number of comets.

273. The earth has one moon, Jupiter four, Saturn seven, and Herschel six moons.

274. All the planets move round the sun from west to east, and the secondary planets move round their primaries in the same direction, excepting those of Herschel,* which move from east to west.

275. The following table will give the diameters of the sun and planets; their mean distances from the sun, and the times in which their annual and diurnal revolutions are performed.

Names.	*Diameters in E. miles.*	*Mean distances from the sun.*	*Diurnal revolution on their own axes.* D. H. M.	*Annual revolutions round the sun.* D. H. M. S.
The Sun,	883,000		25 14 08	
Mercury,	3,200	37,000,000	unknown	87 23
Venus,	7,687	68,000,000	23 22	224 17
Earth,	7,964	95,000,000	23 56	365 05 48 48
Mars,	4,189	144,000,000	24 40	687
Ceres,	160	266,000,000	unknown	1,683
Pallas,	110	266,000,000	unknown	1,683
Juno,		255,000,000	unknown	1,582
Vesta,				
Jupiter,	89,170	490,000,000	9 56	4,332 06
Saturn,	79,042	900,000,000	10 16	10,759 01 51
Herschel,	35,109	1800,000,000	unknown	30,445 18 or about 83 1-2 years.

276. Mercury is the least of all the planets whose magnitudes are accurately known. When seen through a telescope, he appears sometimes in the form of a half moon; hence it is inferred that he has phases like the moon, except that he never

* Some authors contend that the satellites of Herschel move, like other planetary bodies, from west to east.

appears quite round, because his enlightened side is never turned directly towards us, unless when he is so near the sun as to become invisible, by the splendour of his rays. Mercury shines with a bright white light; but, on account of his nearness to the sun and his small size, he is seldom seen—always appearing soon after sunset, and a little before sunrise. The light and heat which this planet receives from the sun, are about seven times greater than the light and heat which the earth enjoys from that luminary. The orbit of Mercury makes an angle of about 7° with the ecliptic, and he revolves round the sun at the rate of about one hundred and nine thousand miles in an hour. Mercury's greatest elongation is 28° 20′.

277. Venus is the brightest, most beautiful, and to appearance, the largest of the planets. Her light is distinguished from that of the other planets by its brilliancy and whiteness. Her light is in some parts of her orbit so great as to cause an object in a dusky place to cast a sensible shadow. When viewed through a telescope, Venus appears to have all the phases of the moon from the crescent to the enlightened hemisphere, though she seldom is seen perfectly round. When Venus is west of the sun, as seen from the earth, that is, when her longitude is less than the sun's longitude, she rises before him in the morning, and is called a morning star; but when she is east of the sun, that is, when her longitude is greater than the sun's, she shines in the evening after the sun sets, and is called an evening star. Venus is a morning star about two hundred and ninety days, and she appears as the evening star for nearly the same length of time, though she performs her whole revolution round the sun, in two hundred and twenty-four days, and seventeen hours. The reason why she appears eastward

or westward of the sun for a longer time than her whole revolution is, that while Venus is going round the sun, the earth is going round him the same way, though slower than Venus; and therefore the relative motion of Venus is slower than her absolute motion. Sometimes Venus is seen on the disc of the sun in the form of a dark, round spot. This appearance can happen but seldom—when Venus thus passes over the sun, she is said to transit that luminary. The last transit of Venus was in 1769, and another will not again occur until the year 1874. The light and heat which this planet receives from the sun are about double the quantity which the earth receives. The orbit of Venus makes an angle of 3° 23′ 35″ with the ecliptic, and she revolves round the sun at the rate of upwards of eighty thousand miles per hour. This planet like Mercury never departs far from the sun, her greatest elongation being only 47° 48′. She is visible only a few hours in the morning before the sun rises, or in the evening after he sets, an evident proof that her orbit, like that of Mercury, is contained within the orbit of the earth, otherwise they would be seen in opposition to the sun, or above the horizon at midnight.

278. The earth is the next planet in the system. Its figure is a sphere depressed at the poles, and protuberent at the equator, having, as before observed, its equatorial diameter, about thirty-four miles longer than its polar diameter, or axis.

279. The sphericity of its form is proved, by the circular shape of its shadow, as projected on the moon during an eclipse; by the appearances exhibited by ships arriving from sea, or leaving the shore, in the first of which cases, the tops of the masts are seen long before the hull becomes visible, and in the other, the hull disappears first,

and the tops of the masts last of all; and by its having been frequently circumnavigated, persons having sailed from a certain port, easterly or westerly, and, keeping the same course, have arrived at the same port again; whereas, if the earth were a plane, this never could have happened, but the longer they continued to sail in the same direction, the more would the distance from the port of departure have increased.

280. The axis of the earth makes an angle of 23° 28′, with a perpendicular to the plane of the ecliptic, and keeps the same oblique direction through its annual course; hence it follows, that during one part of its course, the north pole is turned towards the sun, and during another part of its course, the south pole is turned towards it in the same proportion, which is the cause of the different seasons, as spring, summer, autumn, and winter.—[Fig. 6.]

281. The phenomena of the different seasons of the year, will appear plainly from the following observations. Let A B C D* represent the plane of the earth's annual orbit, having the sun in the focus F; and let *a b*, an imaginary line passing through the centre of the earth, be perpendicular to this plane; and let the axis N S, of the earth, make an angle of 23° 28′ with this perpendicular; then, if the earth move in the direction A, B, C, D, in such a manner that N S may always remain parallel to itself, and preserve the same angle with *a b*, it will point out the seasons of the year; for, suppose a line to be drawn from the centre of the sun to the centre of the earth, it is evident that the sun will be vertical to that part of the earth which is cut by this line. Now, when the earth is in Libra ♎, the sun will appear to be in

* See Fig. C.

Aries ♈, the days and nights will be equal in both hemispheres, and the season a medium between summer and winter; the line dividing the dark and light hemispheres, passes through the two poles N and S, and, consequently, divides all the Parallels of latitude, as P R, into two equal parts; hence, the inhabitants of the whole face of the earth have their days and nights equal, viz. twelve hours each. While the earth moves from Libra ♎ to Capricorn ♑, the north Pole N will become more and more enlightened, and the south pole S will be gradually involved in darkness; consequently, the days in the northern hemisphere will continue to increase in length, and in the southern hemisphere they will decrease in the same proportion, all the parallels of latitude being unequally divided. When the earth has arrived at Capricorn ♑, the sun will appear to be in Cancer ♋, it will be summer to the inhabitants of the northern hemisphere, and winter to those in the southern; the inhabitants at the north pole, and within the arctic circle, will have constant day, and those at the south pole, and within the antarctic circle, will have constant night. While the earth moves from Capricorn ♑ to Aries ♈, the south pole will become more and more enlightened; consequently, the days in the southern hemisphere will increase in length, and in the northern hemisphere they will decrease. When the earth has arrived at Aries ♈, the sun will appear to be in Libra ♎, and the days and nights will again be equal all over the surface of the earth. Again, as the earth moves from Aries ♈ towards Cancer ♋, the light will gradually leave the north pole and proceed to the south; when the earth has arrived at Cancer ♋, it will be summer to the inhabitants in the southern hemisphere, and winter to those in the northern: the

inhabitants of the south pole (if any) will have continual day, those at the north pole, constant night.—Lastly, while the earth moves from Cancer ♋ to Capricorn ♑, the sun will appear to move from Capricorn ♑ to Cancer ♋, and the days in the northern hemisphere will be increasing, while those in the southern will be diminishing in length; and while the earth moves from Capricorn ♑ to Cancer ♋; the sun will appear to move from Cancer ♋ to Capricorn ♑; the days in the northern hemisphere will then be decreasing, and those in the southern hemisphere increasing. In all situations the equator will be divided into two equal parts; consequently, the days and nights at the equator are always equal. Thus, the different seasons of the year are clearly accounted for by the inclination of the earth's axis to the plane of its orbit, combined with the parallel motion of this axis.

282. The motion of the sun, moon, and stars, from east to west every twenty-four hours, is only apparent, and is caused by the rotation of the earth on its axis from west to east in twenty-four hours. This motion of the earth round its axis is called its diurnal or daily motion, and causes the regular return of day and night, and all the celestial appearances before mentioned. Perhaps the reader may think that we should be sensible of the diurnal rotation of the earth, if it really had any such motion. But it is no objection to the earth's rotation that we cannot perceive it. When we sail on smooth water we are scarcely sensible of the motion of the vessel, though it glides swiftly along. On the contrary, objects on the shore, which are fixed and at rest, as houses, trees, &c. seem to move in a direction opposite to that of the vessel. Much less then may we be able to perceive the constant and uniform motion

of such an immense body as the earth, which meets no obstacles in its way to disturb its motion. Besides, we are habituated to the diurnal motion of the earth from our birth, and therefore cannot be so sensible of it as we should be of a new motion. The earth, in its annual progress round the sun, travels at the rate of sixty-eight thousand miles in an hour; and by its diurnal revolution, the inhabitants of the equator are carried round its axis one thousand and forty-two miles in an hour.

283. The moon, being the nearest celestial body to the earth, and, next to the sun, the most resplendent in appearance, has excited the attention of astronomers in all ages.

284. The lunar month is of two sorts. First, periodical, or the time in which the moon finishes her course round the earth, and consists of twenty-seven days, seven hours, forty-three minutes, five seconds. Second, synodical, or the time elapsed from new moon to new moon, and consists of twenty-nine days, twelve hours, forty-four minutes, three seconds.

285. If the earth had no revolution round the sun, or the sun had no apparent motion in the ecliptic, the periodical and synodical month would be the same; but as this is not the case, the moon takes up a longer time to pass from one conjunction to the next, than to describe its whole orbit; or, the time between one new moon and the next is longer than the moon's periodical time. The moon revolves around the earth from west to east, and the sun apparently follows the same course. Now, at the new moon, or when the sun and moon are in conjunction, they both set out from the same place, to move the same way round the earth; but the moon moves much faster than the sun, and consequently will overtake it,

and then there will be another conjunction, or new moon. If the sun had no apparent motion in the ecliptic, the moon would reach the point of conjunction again, after it had gone once round in its orbit; but as the sun moves on in the ecliptic whilst the moon is going round, the moon must move a little more than once round before it comes into conjunction—Hence it is that the time between one conjunction, and the next in succession, is something more than the time which the moon takes in going once through its orbit; and this is the reason why a synodical month is longer than a periodical one.

286. The orbit of the moon is nearly elliptical, having the earth in one of its foci. The eccentricity of the ellipsis is very variable, the moon's motions being disturbed by the action of the sun, are subject to many irregularities.

287. The orbit of the moon is inclined to the ecliptic in an angle which is variable from 5°, to 5° 18′, consequently is inclined in an angle of 5° 9′ at a medium. The motion of the moon's nodes, or points where her orbit intersects the orbit of the earth, is westward, or contrary to the order of the signs; this motion is also irregular, but by comparing together a great number of distant observations, the mean annual retrograde motion is found to be about 19° 19′ 44″, so that the nodes make a complete retrograde revolution from any point of the ecliptic to the same point again in about eighteen years, two hundred twenty-eight days, and six hours.

288. The axis of the moon is almost perpendicular to the plane of the ecliptic; the angle being 88° 17′, consequently it has little or no variation of seasons.

289. The moon turns on its axis from conjunction to conjunction with the sun, in twenty-

nine days, twelve hours, forty-four minutes, three seconds, which is exactly the time it takes to go round its orbit from new moon to new moon; it therefore has the same side constantly turned towards the earth. This is subject however to a small variation, called, The libration of the moon, so that it turns a little more of the one side of its face towards the earth, and sometimes a little more of the other, arising from its uniform motion on its axis, and unequal motion in its orbit; this is called its *libration in longitude*.

290. The moon likewise appears to have a vacillating motion, which presents to our view sometimes more, and sometimes less of the spots on its surface towards each pole; this arises from the axis of the moon making an angle of about 1° 43′ with a perpendicular to the plane of the ecliptic; and, as this axis maintains its parallelism during the moon's revolution round the earth, it must necessarily change its situation to an observer on the earth;—this is called the moon's libration in latitude.

291. While the moon revolves round the earth in an elliptical orbit, it likewise accompanies the earth in its elliptical orbit round the sun; by this compound motion its path is every where concave towards the sun.

292. The moon like the planets shines entirely by light received from the sun, a part of which is reflected to the earth. As the sun can enlighten only one half of a spherical surface at once, it follows, that according to the situation of an observer, with respect to the illuminated part of the moon, he will see more or less of the light reflected from its surface. At the conjunction or time of new moon, the moon is between the earth and the sun, and consequently that side of the moon which is never seen from the earth is en-

lightened by the sun, and that side, which is constantly turned towards the earth, is in total darkness, except the light which is reflected from the earth, and which we do not then perceive. Nor, as the mean motion of the moon in its orbit exceeds the apparent motion of the sun by about 12° 11′ in a day, it follows that it may be seen, in clear weather, about two days after the conjunction; it will be seen in the evening a little to the east of the sun, after he has descended below the western part of the horizon. The convex part of the moon will be towards the west, and the horns or cusps pointing to the east, or if the observer live in north latitude, the horns will appear to the left hand. As the moon continues her motion eastward, a greater part of the surface becomes enlightened, and when 90° eastward of the sun, which will happen in about seven days and eight hours from the new moon, she will come to the meridian at six o'clock in the evening, having the appearance of a bright semicircle, being what is commonly called a half moon. Advancing still eastwardly, she will become more enlightened towards the earth, and at the end of about fourteen and a half days, she will come to the meridian at midnight, being diametrically opposite to the sun, and consequently will appear a complete circle, or be full. The earth is now between the sun and the moon, and that half of her surface which is constantly turned towards the earth is wholly illuminated by the direct rays of the sun, while the other half is involved in darkness. The moon continuing her progress eastward, becomes deficient on her western edge, and in about seven and a third days from the full moon, she is again within 90° of the sun, and appears a semicircle with the convex side towards the sun; moving still onward, in the same direction, the deficiency

on her western edge becomes greater, and she appears a crescent, with the convex side turned towards the east, and her cusps or horns towards the west, and in about fourteen and a half days from the full moon she has again overtaken the sun, this revolution being performed in twenty-nine days, twelve hours, forty-four minutes, and three seconds. Hence, from the new to the full moon, the phases are horned, half moon, and gibbous; and as the convex, or well defined side of the moon, is always turned towards the sun, the horns or irregular side will always appear to the east, or on the left hand of the spectator in north latitude. From the full moon to the next conjunction, the phases are gibbous, half mooned, and horned; the convex side of her face will appear to the east, and the horns or irregular side to the west, or on the right hand of a spectator in north latitude.

293. As the full moons always happen when the moon is directly opposite to the sun, all the full moons in our winter happen when the moon is north of the equinoctial. The moon, while she passes from Aries to Libra, will be visible at the north pole; and invisible in her passage from Libra to Aries; consequently, at the north pole, there is a fortnight's moonlight, and darkness, by turns. The same phenomena will happen at the south pole during the sun's absence in our summer.

294. If the earth, moon, and sun, were all in the same plane, there would be an eclipse of the sun at every new moon, for then the moon is between the earth and the sun; and there would be an eclipse of the moon at every full moon, at which time the earth is between the sun and the moon. But as the orbit of the moon crosses the orbit of the earth or the ecliptic, in two opposite points, called nodes, it is evident that the moon

is never in the ecliptic, except she is in one of these nodes; at all other times she is above or below the orbit of the earth, and though the moon crosses these nodes every month, yet, if there should not be a new or full moon near, or at that time, there will be no eclipse.

295. The moon's distance from the earth is stated in round numbers at two hundred and forty thousand miles from the centre of the earth—her mean distance is calculated to be two hundred thirty-six thousand, eight hundred and forty-seven—her diameter at two thousand one hundred and forty-four miles, and her magnitude about one fiftieth of the magnitude of the earth. She travels at the rate of two thousand two hundred and seventy miles in an hour, round the earth, besides attending the earth in its annual journey round the sun.

296. Reasoning from observation and analogy, we suppose that the moon is a habitable globe. Her surface appears to be variegated with mountains and vallies, plains and oceans, so that we may apply the term terraqueous to that sphere, as well as to the earth, or any other of the primary planets of our system.

297. As the moon illuminates the earth by a light reflected from the sun, she is reciprocally enlightened, but in a much greater degree, by the earth, whose surface is about thirteen times greater than that of the moon. If we suppose the reflecting powers of both surfaces to be equal, the earth will reflect thirteen times more light to the moon, than is received from it. Our earth exhibits the same phases to the moon, that she does to the earth. To the inhabitants of the moon the earth appears to be the largest body in the universe; or about thirteen times as large to them, as the moon appears to us.

298. Mars appears of a dusky red colour, and though sometimes apparently as large as Venus, he never shines with so brilliant a light. This being the first planet beyond the orbit of the Earth, he exhibits to the spectator appearances different from Mercury and Venus. He is sometimes in conjunction with the sun, but was never known to transit his disc; and sometimes he appears directly opposite to the sun, and is seen in the meridian at midnight. These appearances clearly show that Mars moves in an orbit more distant from the sun than that of the earth. Mars revolves on his axis in twenty-four hours and forty minutes; and his polar diameter is to its equatorial, as fifteen to sixteen. The inclination of his orbit to the plane of the ecliptic, is 1° 51′, the place of his ascending node being about 18° in Taurus. This planet travels round the sun at the rate of fifty-five thousand two hundred and twenty-three miles per hour.

299. The planets, or asteroids, whose orbits are included between those of Mars and Jupiter, were discovered in the following order.

300. 1. Ceres. On the 1st of January, 1801, M. Piazzi, astronomer royal, at Palermo, discovered a new planet between the orbits of Mars and Jupiter, generally called Ceres Ferdinandia from the island in which it was discovered; and Ferdinand the fourth, King of the two Sicilies. The elements of the theory of this planet are imperfectly known. It appears like a star of the eighth magnitude, and consequently is invisible to the naked eye.*

301. 2. Pallas was discovered by Dr. Olbers, of Bremen, March 28, 1802.†

* See Table, page 60. † Ibid.

302. 3. Juno was discovered September 1st, 1804, by M. Harding, of Lilienthal, in the duchy of Bremen.

303. 4. On the 29th of March, 1807, Dr. Olbers discovered a fourth new planet, called Vesta. Its size appears like a star of the fifth magnitude.

304. Jupiter is the largest of all the planets, and, notwithstanding his great distance from the sun and the earth, he appears to the naked eye almost as large as Venus, though his light is less brilliant. Jupiter, when in opposition to the sun, is much nearer to the earth, than he is a little before and after his conjunction with the sun; hence, at the time of opposition, he appears larger and more luminous than at other times. When the longitude of Jupiter is less than that of the sun, he will be a morning star, and appear in the east before the sun rises; but when his longitude is greater than the sun's, he will appear in the west after the sun sets.

305. Jupiter revolves on his axis in nine hours, fifty-six minutes, which is the length of his day; but as his axis is nearly perpendicular to the plane of his orbit, he has no diversity of seasons. This planet is surrounded by faint substances called belts or zones, which, from their frequent change in number and situation, are supposed to consist of clouds.

306. The inclination of the orbit of Jupiter to the plane of the ecliptic, is 1° 18′ 56″, and the place of his ascending node, is 8° in Cancer. He moves in his orbit at the rate of twenty-nine thousand eight hundred and ninety-four miles per hour. On account of the great magnitude of Jupiter, and his rapid rotation on his axis, he is more flattened at the poles, than the earth.

307. Jupiter is attended by four satellites or moons, each of which revolves round him in the

same manner as the moon revolves around our earth. The times of their periodical revolutions round their primary planet, and their respective distances from his centre, are given in the following table,

Satellites.	*Periodical revolution.* D.	H.	M.	S.	*Distance from Jupiter in semi diameters.*	*Distance from Jupiter in English miles.*
I.	1	18	27	33	6 67	252,511
II.	3	13	13	42	9 00	400,810
III.	7	3	42	33	14 38	640,406
IV.	16	16	32	18	25 30	1,126,723

308. The satellites of Jupiter are invisible to the naked eye. They were discovered by Galileo, the inventor of telescopes, in the year 1610. This was an important discovery; for as the satellites revolve around Jupiter in the same direction in which he revolves round the sun, they are frequently eclipsed by his shadow, and afford an excellent method of finding the true longitude of places on land. To these eclipses we also owe the discovery of the progressive motion of light, which is found to travel from the sun to the earth, in eight minutes, thirteen seconds.

309. The first of Jupiter's satellites is the most important, on account of its numerous eclipses. The times of the eclipses of the satellites of Jupiter are calculated for the meridian of Greenwich, and inserted in the third page of the Nautical Almanack for every month, and their configuration, or appearances with respect to Jupiter, are to be found in the twelfth page of the same work. As the earth turns on its axis at the rate of fifteen degrees in an hour, or one degree in four minutes of time, a person, one degree westward of Greenwich, will observe the emersion or immersion of any one of the four satellites of Jupiter four minutes later than the time mentioned

in the Nautical Almanack; and if he be one degree eastward of Greenwich, he will see the eclipse four minutes sooner than the time at Greenwich. These eclipses must be observed with a good telescope, and a pendulum clock that beats seconds or half seconds.

310. Saturn shines with a pale, feeble light, being the farthest from the sun of any planet that is distinctly visible without the aid of a telescope. His disc is crossed by zones or belts like those of Jupiter. The inclination of the orbit of Saturn to the ecliptic is about 2° 29′ 50″, and the place of his ascending node, about 21° in Cancer. Saturn proceeds in his orbit, at the rate of twenty-two thousand and seventy-two miles per hour. The equatorial diameter of Saturn is to the polar diameter as eleven to ten. Saturn is attended by seven satellites.

311. The ring of Saturn is a broad and opaque circular arch, surrounding the body of the planet, without touching it, like the wooden horizon of an artificial globe. Dr. Herschel says that this ring is really composed of two concentric rings. The breadth of the ring is about twenty-one thousand miles, and the space between it and the body of the planet is supposed to be equal to its breadth. Of its use to the inhabitants of Saturn, we are ignorant, though the most probable conjecture is, that it reflects the light of the sun, and assists in illuminating and warming that distant planet.

312. The ring of Saturn revolves round the axis of Saturn, and in a plane coincident with the plane of his equator, in ten hours, thirty-two minutes, five and a quarter seconds. The ring being a circle, appears elliptical, from its oblique position; and it appears most open when Saturn's longitude is about 2 signs 17 degrees, or 8 signs 7 degrees.

313. Herschel, or the Georgium Sidus, is the remotest of all the known planets belonging to the solar system, and was discovered by Dr. Herchel, at Bath, in England, on the 13th of March, 1781. This planet is called Ournâus by the Royal Prussian Academy, and by some others, because the other planets are named from such of the heathen Deities as were relatives. This planet, when viewed through a telescope of small magnifying power, appears like a star of between the sixth and seventh magnitude. It may be seen by a good eye without a telescope, in a fine clear night when the moon is not above the horizon. The Georgium Sidus is attended by six satellites, which were all discovered by Dr. Herschel. Their orbits are said to be nearly perpendicular to the ecliptic, and what is still more singular, their revolutions are performed round their primary, in a retrograde order, or contrary to the order of the signs.

314. Though the primary planets already described, and their satellites, are considered as the regular bodies which form the solar system, yet that system is sometimes visited by other bodies called *Comets*, which are supposed to move round the sun in elliptical, and very eccentric orbits, so that they become invisible in their aphelion. Their theory is very imperfect. Sir Isaac Newton observes that comets are compact, solid, and durable bodies, which move in very oblique and eccentric orbits, with the greatest freedom, and preserve their motions for an exceeding long time, even when moving contrary to the course of the planets. Their tail is a very subtle, attenuated vapour, emitted by the head or nucleus of the comet, ignited or intensely heated by the sun. This tail is always opposite to the sun, and when seen in different directions from the earth, gives

different appearances and names to the same comet. Comets are very numerous—upwards of four hundred and fifty are supposed to have visited, or to belong to our system.

315. Concerning eclipses of the sun and moon, it may be further observed.* The dark part of the moon's shadow is called the umbra, and the lighter part the penumbra. Eclipses are, under particular circumstances of situation to a spectator on the earth, invisible, visible, partial, annular, and total.

316. An eclipse of the sun begins on the western side of the disc, and ends on the eastern; and an eclipse of the moon begins on the eastern side of her disc, and ends on the western.

317. The average number of eclipses in a year is four, two of the sun, and two of the moon; and as the sun and moon are as long below the earth as they are above it, the average number of visible eclipses in a year is two, one of the sun, and one of the moon. The lunar eclipse frequently happens a fortnight after the solar one, or the solar one a fortnight after the lunar one. The most general number of eclipses in any year is four; there are sometimes six eclipses in a year, but there cannot be more than seven, nor less than two.

318. The ecliptic limits of the sun are greater than those of the moon; and hence there will be more solar than lunar eclipses, in nearly the ratio of three to two; but more lunar than solar eclipses are visible, because a lunar eclipse is visible to a whole hemisphere at once; whereas a solar eclipse is visible only to a part of a hemisphere.

319. A tide is that motion of the water in the seas and rivers by which they are found to rise

* Vide Definitions, 229, 230.

and fall in a regular succession, and this flowing and ebbing is caused by the attraction of the sun and moon. They ebb and flow twice in twenty-four hours.

320. The parts of the earth directly under the moon, or when the moon is in their zenith, and those diametrically oppósite to them, or under the nadir, will have high water at the same time.

321. Those parts of the earth which are 90° from the places which have the moon in the zenith, have at the same time ebb, or low water.

322. The tides are greater than ordinary twice in every month, viz. at the times of the new and full moon; and these are called spring tides.

323. The tides are less than ordinary twice in every month, that is, about the time of the first and last quarters of the moon; and these are called neap tides.

324. When the moon is nearest to the earth, the tides increase more in similar circumstances than at other times.

325 The spring tides are greater a short time before the vernal equinox, and after the autumnal equinox, than at any other time in the year.

326. Lakes are not subject to tides, and small inland seas are also little affected by them; they are also inconsiderable in high northern or southern latitudes.

327. The time of the tides, happening in particular places, and their height, may be very different, according to the situation of those places. For the motion of the tides is propagated swifter in the open sea, and slower through channels or shallow places; and being retarded by such impediments, the tides cannot rise so high as where the waters have free and ample liberty of action.

328. The morning tides differ generally in their rise from the evening tide. In winter the morning tides are highest, and in summer the evening tides. The new and full moon spring tides rise to different heights. The tides follow the course of the moon, i. e. from east to west, where they meet with no impediment.

329. Theory of tides. The earth is demonstrably within the sphere of the attraction of the sun and moon. Were the terraqueous globe entirely free from their influence, the ocean, being equally attracted an all sides towards the centre, would continue in a state of perfect stagnation, and would neither ebb nor flow. But as the case is otherwise it must be affected by the attraction of the two great luminaries, and rise higher in those places where its gravity, or tendency to the centre of the earth, is most diminished. This being premised, let us consider the globe of the earth, as covered with a deep sea; it will then follow that by the yielding of the fluid to the lunar attraction, the earth will assume the form of a spheroid, whose longest diameter, if prolonged, would pass through the moon; that is, wherever the moon is vertical, she will not only raise the water under her towards the zenith, but also at the same time in the nadir or opposite point. She raises the water in the former, because the fluid there is nearly four thousand miles nearer to her attractive power, than to the centre of the earth; it therefore gravitates less, and becomes lighter than in those parts which may be described as lying in a line passing through the centre of the world at right angles, with one supposed to be drawn perpendicularly to it from the zenith, as A D;* the waters of course press towards

* See Fig. 5.

the zenith, or part under the moon, where they form an accumulation or swell of the sea. Now, as the earth and waters gravitate towards the moon, it will follow that the parts of water nearer to the moon than the earth, will rise into the zenith, whereas the parts of the water that are farther from the moon than the earth, will be less attracted, and flow into the nadir; by which means tides are raised in the zenith and nadir at the same time.

330. Demonstration. Because the power of gravity decreases as the squares of the distances increase.* Suppose the earth to be entirely covered with a fluid as A B Z, C D, Q N, and the sun and moon to have no effect upon them, it is evident that all the particles, being equally attracted towards the centre of the earth O, would form an exact spherical surface, except that by the revolution of the earth on its axis; the attraction from B towards O, and from O to the opposite point, being the equatorial parts, would be a little diminished by the centrifugal force. Let the moon at M now exert her influence on the water; then, because the power of attraction decreases as the squares of the distance increase, those parts will be most attracted which are nearest to the moon, and their tendency towards O will be diminished; the waters at Z B will therefore rise, and at Z, which is nearest the moon, they will be highest. At the same time the waters in the nadir at N are elevated in a similar manner. The waters at A B Z C D, being more attracted by the moon than the central parts at O, and the central parts more attracted then the surface at N, the opposite part of the earth, the distance between the centre of the earth, and the

* See Fig. 5.

surface of the water under the zenith and nadir will be increased. For let three bodies Z O M be equally attracted by M, then it will follow, that they will all move equally fast towards M, and their mutual distances will continue the same, but if the bodies are unequally attracted, the body which is most attracted will move the fastest, and its distance from the other bodies will be increased. Now, by the law of gravitation M will attract Z more strongly than it does O, by which means the distance between Z and O will be increased; in like manner O will be more strongly attracted than N, by which means the distance between O and N will be increased. Now suppose a number of bodies, A B Z C D F N E, placed round O to be attracted by M, the parts Z and N will have their distances increased, while the parts at A D will not recede from each other, but will rather approach nearer to O, by the oblique attraction of M. Hence, if the whole earth were composed of similar bodies to A B Z C D F N E, and to be similarly attracted by M, the section of the earth, formed by a plane passing through the centre of the earth, and the moon could be a figure resembling an ellipsis, having its larger axis Z N, directed towards the moon, and its shorter axis A D in the horizon. The figure of the earth, therefore, would be an oblong spheroid, having its larger axis directed towards the moon; consequently, it will be high water in the zenith and nadir, and low water in the horizon, or line A D, at the same time; and as the earth turns round on its axis from the moon, to the moon again, in about twenty-four hours, forty-eight minutes, there will be two tides of flood and two of ebb in that time, agreeably to experience.

331. The time of high water is not precisely at the time of the moon's coming to the meridian, but about an hour after; for the moon acts with some force after she has passed the meridian, and by that means adds to the libratory, or waving motion, which the waters had acquired when she was on the meridian.

332. In the foregoing observations and demonstration, the influence of the moon has only been considered. The attractive power of the sun on the waters is also great, but not equal to that of the moon. It is computed that the moon's attraction on the sea is about four times as great as the sun's. The highest tides are occasioned by the combination of the solar and lunar influences, at the times of the new and full moon.

333. After this imperfect survey of the heavens, and of the portion of the universe to which we belong, we cannot but feel the force of Dr. Young's assertion, "An undevout astronomer is mad." To the Epicureans of the Roman and Grecian schools, who taught the impious doctrine that creation was the production of blind and undesigning chance, Cicero opposed unanswerable arguments drawn from ethical and philosophical observations on the natural world, and the phenomena which he beheld in the all-surrounding heavens. To the Atheist of the present day, let me earnestly recommend an attentive perusal of the Roman moralist's second book on the Nature of the Gods. "Is he," says that illustrious author, "worthy to be called a man, who attributes to chance, not to an intelligent cause, the constant motions of the celestial bodies; the regular courses of the stars; the agreeable proportion and connexion of all things, *conducted with so much reason, that our reason itself is lost in the inquiry?* When we see various machines moving

artificially, do we doubt whether they are the productions of reason? And when we behold the heavens moving with a prodigious celerity, and causing an annual succession of the different seasons of the year, which vivify and preserve all things, can we doubt that this world is directed, I will not say only *by reason*, but by REASON MOST EXCELLENT AND DIVINE. For, in short, there is no need to seek after proofs;—we need only contemplate the beauty of those objects, which, we assert, are created and organized by a DIVINE PROVIDENCE."

PROBLEMS, &c.

The skeleton of a plain chart, which I have introduced in this work, is designed to render the various circles, parallels, zones, &c. familiar to learners, by inspection. It will also be an easy, instructive, and entertaining exercise, to lay down places on it according to their situation on the globe. By frequently performing the following problems, the young geographer will not only acquire an accurate knowledge of the relative sites of different countries, cities, &c. and of the distances between them, but he will, by filling up his skeleton map, have the pleasure of seeing them delineated on a production of his own ingenuity and labour. This map comprises the degrees of longitude as high as 90, on each side of the first meridian, and all the degrees of latitude, from pole to pole.

PROBLEM I. (*For the Skeleton map.*)

The latitude and longitude of a place being given, to lay it down on the skeleton map.

Rule. Lay a ruler across the map, on the degree of given latitude found in one of the sides, then, from the nearest meridian to the given longitude, set off with the compasses as many degrees from that meridian, as the longitude is over the number of degrees through which the meridian runs, keeping the compasses close to the ruler—then, one foot being on the meridian line, under the other foot will be the situation required.—The odd degrees may be taken from the scale.

Thus, I wish to lay down the city of Petersburgh. On looking into the table, I find its latitude to be 59° 56′ north, and its longitude 30° 19′ east. I lay a ruler across the map just under the figure 60 in the side of the map, and in north latitude. On observing the top of the map, I see a meridian line running through the 30th° of east longitude, consequently the place of Petersburgh is close to the point where the meridian and the ruler intersect each other. If the longitude had been in any number of degrees between 30 and 40, for instance 35°, I should have extended my compasses 5 degrees taken from the scale, and setting one foot of them in the meridian 30 close to the ruler's edge, the other foot kept also close to the edge of the ruler, would have shewn the point of situation. This example will serve for any other place, always observing to take the nearest meridian whose number is *less* than the longitude given.

PROBLEM II.

The latitude and longitude of a place being given, to find it on a map, on a plain, or mercator's projection.

Rule. Lay a ruler across the given latitude; observe in the top of the map the nearest meridian to the given longitude. If a meridian run through the given degree, the place will be found in the point where the meridian and ruler intersect each other. Thus Petersburgh having 30° 19′ of longitude, and 59° 56′ latitude, it will be seen just in the point of intersection. If the longitude had been 34°, the 4° should have been taken from the scale, then one foot being set close to the edge of the ruler on the meridian at 30°, the other would have extended to the distance required.

PROBLEM III.

To find the latitude and longitude of a place, on a plain, or mercator's chart or map.

Rule. Lay a ruler over the place, directly across the map, and you will find its latitude in degrees and minutes in the side row of figures; then lay the ruler over the place, up and down the map, and in the top or bottom row of figures, or on the equator, you will find the longitude.

To solve the foregoing problem on a map, on a globular projection—observe,

To find the latitude of a place, measure its distance from the nearest parallel of latitude, with the compasses, if in north latitude from the next parallel *below*, in south latitude *above* it—then from the termination of that parallel in the side row of figures, measure, with the same extent, the number of degrees from it, which, added to the number of degrees at the termination of the parallel, will give the latitude required. Then, with the compasses, measure the distance of the place from the nearest meridian, to the *left*, if in *east*; and to the *right*, if in *west* longitude, and see on the scale, or any graduated circle, how many degrees that extent of compasses includes—that number of degrees added to the number of degrees through which the meridian passes will give the longitude required.

PROBLEM IV.

To find the distance between two places on a map.

Set one foot of the compasses on one of the places, and extend the other foot until it reach the second given place—apply the compasses, with this extent, to any scale of degrees on the map, and the number of degrees included between the feet of the compasses, multiplied by 60, will

give the distance in geographical, or by 69½ in English miles: on some maps there are scales of miles, convenient for use without calculation. If the places be too far apart for the feet of the compasses to reach them, a piece of string or narrow tape, extended from the one to the other, and then applied to the scale on the equator, or any other extensive scale, will shew the distance in degrees.

PROBLEM V.*

The difference of longitude between two places being given, to find the difference of time at any given hour.

Rule. Multiply the difference by 4, and divide the product by 60.

The sun passes through 4 degrees of longitude in 1 minute of time.

Required the time at Petersburgh, London, Paris, Calcutta, and the most westerly part of South America, when it is noon at Boston.

Boston 71° W.
Petersburgh 30° E.

101 difference.
4

60 | 404 | 6h. 44°.
360

44

Petersburgh being east of Boston, the time at that place is past noon. If the problem be reversed, the time at Boston will be before noon.

N. B. If the longitudes be of different names, and when added together produce a larger sum than 180°, deduct that sum from 360° and proceed with the remainder for the true difference—for instance,

* To find the difference of longitude between two places, see problem VIII. page 92.

The long. of Boston is 71 W.
Canton 112 E.

```
183——360
     183
     ———
     177
       4
     ———
  60|708| 11h. 48°
     60
     ———
     108
      60
     ———
      48
```

Problems performed by the Terrestrial Globe.

PROBLEM I.

To find the latitude of any given place.

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles; the degree above the place is the latitude. If the place be on the north side of the equator, the latitude is north; if it be on the south side, the latitude is south.

On small globes the latitude of a place cannot be found nearer than to about a quarter of a degree. Each degree of the brass meridian on the largest globes is generally divided into three equal parts, each part containing twenty geographical miles; on such globes the latitude may be found to 10′.

Examples. 1. What is the latitude of Edinburgh? *Answer.* 56° north.

2. Required the latitude of the following places;

Amsterdam	Florence	Philadelphia
Archangel	Gibraltar	Quebec
Barcelona	Hamburgh	Rio Janeiro

PROBLEM II.

To find all those places which have the same latitude as any given place.

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles, and observe its latitude; turn the globe round, and all places passing under the observed latitude are those required.

Example. What places have the same or nearly the same latitude as Madrid?

Answer. Minorca, Naples, Constantinople, Samarcand, Philadelphia, &c.

PROBLEM III.

To find the longitude of any place.

Rule. Bring the given place to the brass meridian, the number of degrees on the equator, reckoning from the meridian passing through London to the brass meridian, is the longitude. If the place lie to the right hand of the meridian passing through London, the longitude is east; if to the left hand, the longitude is west.

Examples. 1. What is the longitude of Petersburgh?

Answer. $30\frac{1}{4}°$ east.

2. What is the longitude of Philadelphia?

Answer. $75\frac{1}{4}°$ west.

3. Required the longitude of the following places:

Aberdeen	Civita Vecchia	Lisbon
Alexandria	Constantinople	Madras

4. What is the greatest longitude a place can have?

PROBLEM IV.

To find all those places that have the same longitude as a given place.

RULE. Bring the given place to the brass meridian, then all places under the same edge of the meridian from pole to pole have the same longitude.

All people situated under the same meridian, from 66° 28′ north latitude to 66° 28′ south latitude, have noon at the same time; or, if it be one, two, three, or any number of hours before or after noon with one particular place, it will be the same hour with every other place situated under the same meridian.

Examples. 1. What places have the same, or nearly the same longitude as Stockholm?

Answer. Dantzic, Presburgh, Tarento, the Cape of Good Hope, &c.

2. What places have the same longitude as Alexandria?

3. When it is ten o'clock in the evening at London, what inhabitants of the earth have the same hour?

PROBLEM V.

To find the latitude and longitude of any place.

RULE. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles; the degree above the place is the latitude, and the degree on the equator, cut by the brass meridian, is the longitude.

This problem is only an exercise of the first and third.

Examples. 1. What are the latitude and longitude of St. Petersburgh?

Answer. Latitude 60° N. longitude 30¼° E.

2. Required the latitudes and longitudes of the following places:

Acapulco	Cusco	Leith
Aleppo	Copenhagen	Lizard Point.
Algiers	Durazzo	Lubec

PROBLEM VI.

To find any place on the globe, having the latitude and longitude of that place given.

Rule. Find the longitude of the given place on the equator, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; then, under the given latitude, on the brass meridian, you will find the place required.

Examples. 1. What place has 151½° east longitude, and 34° south latitude.

Answer. Botany Bay.

2. What places have the following latitudes and longitudes?

Latitudes.	*Longitudes.*	*Latitudes.*	*Longitudes.*
50° 6′ N.	5° 54′ W.	19° 26′ N.	100° 6′ W.
48 12 N.	16 16 E.	59 56 N.	30 19 E.
55 58 N.	3 12 W.	0 13 S.	77 55 W.

PROBLEM VII.

To find the difference of latitude between any two places.

Rule. Find the latitudes of both the places (by Prob. I.) Then, if the latitudes be both north or both south, subtract the less latitude from the greater, and the remainder will be the difference of latitude: but, if the latitudes be one north and the other south, add them together, and their sum will be the difference of latitude.

Examples. 1. What is the difference of latitude between Philadelphia and St. Petersburgh?

Answer. 20 degrees.

2. What is the difference of latitude between Madrid and Buenos Ayres?

Answer. 75 degrees.

3. Required the difference of latitude between the following places:

London and Rome.
Delhi & Cape Comorin.
Vera Cruz and Cape Horn.
Alexandria and the Cape of Good Hope.
Pekin and Lima.

4. What two places on the globe have the greatest difference of latitude?

PROBLEM VIII.

To find the difference of longitude between any two places.

Rule. Find the longitudes of both the places (by Prob. III.) then, if the longitudes be both east or both west, subtract the less longitude from the greater, and the remainder will be the difference of longitude: but, if the longitudes be one east and the other west, add them together, and their sum will be the difference of longitude.

When this sum exceeds 180 degrees, take it from 360, and the remainder will be the difference of longitude.

Examples. 1. What is the difference of longitude between Barbadoes and Cape Verd?

Answer. 41° 48′

2. What is the difference of longitude between Buenos Ayres and the Cape of Good Hope?

Answer. 76° 50′.

3. Required the difference of longitude between the following places.

Vera Cruz & Canton.
Bergen and Bombay.
Columbo and Mexico.
Constantinople & Batavia.
Bermudas Island and Isl- and of Rhodes.

4. What is the greatest difference of longitude comprehended between two places?

PROBLEM IX.

To find the distance between any two places.

Rule. The shortest distance between any two places on the earth, is an arch of a great circle contained between the two places. Therefore, lay the graduated edge of the quadrant of altitude over the two places, so that the division marked O may be one of the places, the degrees on the quadrant comprehended between the two places will give their distance; and if these degrees be multiplied by 60, the product will give the distance in geographical miles; or multiply the degrees by 69½, and the product will give the distance in English miles.

Or, Take the distance between the two places with a pair of compasses, and apply that distance to the equator, which will shew how many degrees it contains.

If the distance between the two places should exceed the length of the quadrant, stretch a piece of thread over the two places, and mark their distance; the extent of thread between these marks, applied to the equator, from the meridian of London, will shew the number of degrees between the two places.

*A Table of the number of Geographical and English miles which make a degree in any given parallel of latitude.**

Deg. Lat.	Geog. Miles.	English Miles	Deg. Lat.	Geog. Miles.	English Miles.	Deg. Lat.	Geog. Miles.	Eng. Miles.
0	60,00	69,07	31	51,43	59,13	61	29,09	33,45
1	59,99	69,06	32	50,88	58,51	62	28,17	32,40
2	59,96	69,03	32	50,32	57,87	63	27,24	31,33
3	59,92	68,97	34	49,74	57,20	64	26,30	30,24
4	59,85	68,90	35	49,15	56,51	65	25,36	29,15
5	59,77	68,81	36	48,54	55,81	66	24,40	28,06
6	59,67	68,62	37	47,92	55,10	67	23,45	26,96
7	59,55	68,48	38	47,28	54,37	68	22,48	25,85
8	59,42	68,31	39	46,63	53,62	69	21,51	24,73
9	59,26	68,15	40	45,90	52,85	70	20,52	23,60
10	59,09	67,95	41	45,28	52,07	71	19,53	22,47
11	58,89	67,73	42	44,59	51,27	72	18,54	21,32
12	58,69	67,48	43	43,88	50,46	73	17,54	20,17
13	58,46	67,21	44	43,16	49,63	74	16,54	19,02
14	58,22	66,95	45	42,43	48,78	75	15,53	17,86
15	57,95	66,65	46	41,68	47,93	76	14,52	16,70
16	57,67	66,31	47	40,92	47,06	77	13,50	15,52
17	57,38	65,98	48	40,15	46,16	78	12,48	14,35
18	57,06	65,62	49	39,36	45,26	79	11,45	13,17
19	56,73	65,24	50	38,57	44,35	80	10,42	11,98
20	56,38	64,84	51	37,76	43,42	81	9,38	10,79
21	56,01	64,42	52	36,94	42,48	82	8,35	9,59
22	55,63	63,97	53	36,11	41,53	83	7,31	8,41
23	55,23	63,51	54	35,27	40,56	84	6,27	7,21
24	54,81	63,03	55	34,41	39,58	85	5,22	6,00
25	54,38	62,53	56	33,55	38,58	86	4,18	4,81
26	53,93	62,02	57	32,68	37,58	87	3,14	3,61
27	53,46	61,48	58	31,79	36,57	88	2,09	2,41
28	52,97	60,93	59	30,90	35,54	89	1,05	1,21
29	52,48	60,35	60	30,00	34,50	90	0,00	0,00
30	51,96	59,75	*Length of a degree 69,07 English miles.*					

* For the principle on which this table is constructed, see Keith's Trigonometry, page 249.

Examples. 1. What is the shortest distance between London and Botany Bay?

154 distance in degrees.	154 distance in degrees.
60	69 1-2
9240 geographical miles.	77
	1386
	924
	10703 English miles.

2. What is the direct distance between London and Jamaica, in geographical and in English miles?

3. What is the extent of Europe in English miles, from cape Matapan in the Morea, latitude 36° 35′ N. to the North Cape in Lapland, latitude 71° 30′ N.? The places being situated nearly due north and south.

4. What is the extent of south America from cape Blanco in the west, to cape St. Rouge in the east?

PROBLEM X.

Given the latitude of a place and its distance from a given place, to find that place whereof the latitude is given.

Rule. If the distance be given in English or geographical miles, turn them into degrees by dividing by 69½ for English miles, or 60 for geographical miles; then put that part of the graduated edge of the quadrant of altitude which is marked O, upon the given place, and move the other end eastward or westward (according as the required place lies to the east or west of the given place) till the degrees of distance cut the given parallel of latitude; under the point of intersection you will find the place sought.

Or, having reduced the miles into degrees, take the same number of degrees from the equa-

tor with a pair of compasses, and with one foot of the compasses in the given place, as a centre, and this extent of degrees, describe a circle on the globe; turn the globe till this circle falls under the given latitude in the brass meridian, and you will find the place required.

Examples. 1. A place in latitude 60° N. is 1320½ English miles from London, and it is situated in E. longitude; required the place?

Answer. Divide 1320½ miles by 69½ miles, or, which is the same thing, 2641 half miles by 139 half miles, the quotient will give 19 degrees; hence the required place is Petersburgh.

2. A place in latitude 32½° N. is 1350 geographical miles from London, and is situated in W. longitude; required the place?

Answer. Divide 1350 by 60, the quotient is 22° 30′, or 22½ degrees; hence the required place is the west point of the island of Madeira.

3. What place, in W. longitude and 13° N. latitude, is 3660 geographical miles from London?

PROBLEM XI.

Given the longitude of a place and its distance from a given place, to find that place whereof the longitude is given.

Rule. If the distance be given in English or geographical miles, turn them into degrees by dividing by 69½ for English miles, or 60 for geographical miles; then put that part of the graduated edge of the quadrant of altitude which is marked O, upon the given place, and move the other end northward or southward (according as the required place lies to the north or south of the given place,) till the degrees of distance cut the given longitude: under the point of intersection you will find the place sought.

Or, having reduced the miles into degrees, take the same number of degrees from the equator with a pair of compasses, and with one foot of the compasses in the given place, as a centre, and this extent of degrees, describe a circle on the globe; bring the given longitude to the brass meridian, and you will find the place, upon the circle, under the brass meridian.

Examples. 1. A place in north latitude, and in 60 degrees west longitude, is 4239½ English miles from London; required the place?

Answer. Divide 4239½ miles by 69½ miles, or, which is the same thing, 8479 half miles by 139 half miles, the quotient will give 61 degrees; hence the required place is the island of Barbadoes.

2. A place in north latitude, and in 75½ degrees west longitude, is 3120 geographical miles from London; what place is it?

PROBLEM XII.

To find how many miles make a degree of longitude in any given parallel of latitude.

Rule. Lay the quadrant of altitude parallel to the equator, between any two meridians in the given latitude, which differ in longitude 15 degrees;* the number of degrees intercepted between them multiplied by 4, will give the length of a degree in geographical miles. The geographical miles may be brought in English miles by multiplying by 116, and cutting off two figures from the right hand of the product.

* The meridians on Cary's globes are drawn through every ten degrees. The rule will answer for these globes, by reading ten degrees for 15 degrees, and multiplying by 6 instead of 4.

Or, take the distance between two meridians, which differ in longitude 15 degrees in the given parallel of latitude, with a pair of compasses; apply this distance to the equator, and observe how many degrees it makes; with which proceed as above.

Since the quadrant of altitude will measure no arch truly but that of a great circle; and a pair of compasses will only measure the chord of an arch, not the arch itself; it follows, that the preceding rule cannot be mathematically true, though sufficiently correct for practical purposes. When great exactness is required, recourse must be had to calculation.

Examples. 1. How many geographical and English miles make a degree in the latitude of Pekin.

Answer. The latitude of Pekin is 40° north: the distance between two meridians in that latitude (which differ in longitude 15 degrees) is 11½ degrees. Now, 11½ degrees multiplied by 4, produces 46 geographical miles for the length of a degree of longitude, in the latitude of Pekin; and, if 46 be multiplied by 116, the product will be 5336; cut off the two right hand figures, and the length of a degree in English miles will be. 53 Or, by the rule of three, 15° : 69½°m. : : 11½ : 53 miles.

2. How many miles make a degree in the parallels of latitude wherein the following places are situated?

Surinam.	Washington.	Spitzbergen.
Barbadoes.	Quebec.	Cape Verd.
Havannah.	Skalholt.	Alexandria.
Bermudas I.	North Cape.	Paris.

PROBLEM XIII.

To find the bearing of one place from another.

RULE. If both the places be situated on the same parallel of latitude, their bearing is either east or west from each other; if they be situated on the same meridian, they bear north and south from each other; if they be situated on the same rhumb-line, that rhumb-line is their bearing; if they be not situated on the same rhumb-line, lay the quadrant of altitude over the two places, and that rhumb-line which is the nearest of being parallel to the quadrant will be their bearing.

Examples. 1. Which way must a ship steer from the Lizard to the island of Bermudas?

Answer. W. S. W.

2. Which way must a ship steer from the Lizard to the island of Madeira?

Answer. S. S. W.

3. Required the bearing between London and the following places?

Amsterdam.	Copenhagen.	Petersburg.
Athens.	Dublin.	Prague.
Bergen.	Edinburgh.	Rome.

PROBLEM XIV.

To find the Antœci, Pariœci, and Antipodes of any place.

RULE. Place the two poles of the globe in the horizon, and bring the given place to the eastern part of the horizon; then, if the given place be in north latitude, observe how many degrees it is to the northward of the east point of the horizon; the same number of degrees to the southward of the east point will shew the Antœci; an equal number of degrees, counted from the west point of the horizon towards the north, will shew the

Periœci; and the same number of degrees, counted towards the south of the west, will point out the Antipodes. If the place be in south latitude the same rule will serve by reading south for north, and the contrary.

As the hour circle of some globes is placed on the outside of the brass meridian, and the poles cannot be placed in the horizon: the following method of solving this problem may be adopted.

FOR THE ANTŒCI.

Bring the given place to the brass meridian, and observe its latitude; then in the opposite hemisphere under the same degree of latitude the Antœci will be found.

FOR THE PERIŒCI.

Bring the given place to the brass meridian, and observe its latitude, and set the index of the hour circle to 12; turn the globe until the index points to the lower 12; then under the degree of latitude of the given place, the Periœci will be found; and,

FOR THE ANTIPODES.

Keep the globe in the same position, and cast the eye along the brass meridian, till a similar degree of latitude in the *opposite* hemisphere is observed, under that degree, is the place of the Antipodes.

Examples. 1. Required the Antœci, Periœci, and Antipodes of the island of Bermudas?

Answer. A place in Paraguay, a little N. W. of Buenos Ayres, is the Antœci; the Periœci is a place in China N. W. of Nankin; and the S. W. part of New Holland is the Antipodes.

2. Required the Antœci, Periœci, and Antipodes, of the Cape of Good Hope?

3. Captain Cook, in one of his voyages, was in 50 degrees south latitude and 180 degrees of longitude; in what part of Europe were his Antipodes?

PROBLEM XV.

To find at what rate per hour the inhabitants of any given place are carried, from west to east, by the revolution of the earth on its axis.

RULE. Find how many miles make a degree of longitude in the latitude of the given place, (by Problem XII.) which multiply by 15 for the answer.*

Or, look for the latitude of the given place in the table, Problem IX, against which you will find the number of miles contained in one degree; multiply these miles by 15, and reject two figures from the right hand of the product; the result will be the answer.

Examples. 1. At what rate per hour are the inhabitants of Madrid carried from west to east by the revolution of the earth on its axis.

Answer. The latitude of Madrid is about 40° N. where a degree of longitude measures 46 geographical, or 53 English miles (see Example 1. Problem XI.) Now 46 multiplied by 15 produces 690, and 53 multiplied by 15 produces 795: hence, the inhabitants of Madrid are carried 690 geographical, or 795 English miles per hour.

* The reason of this rule is obvious, for, if *m* be the number of miles contained in a degree, we have 24 hours : 360° $\times$ m : : 1 hour to the answer; but, 24 is contained 15 times in 360; therefore, 1 hour : 15 $\times$ m : : 1 hour to the answer: that is, on a supposition that the earth turns on its axis from west to east in 24 hours; but we have before observed that it turns on its axis in 23 hours 56 minutes 4 seconds, which will make a small difference not worth notice.

2. At what rate per hour are the inhabitants of the following places carried from west to east by the revolution of the earth on its axis?

Skalholt.	Philadelphia.	Cape of Good Hope.
Spitzbergen.	Cairo.	Calcutta.
Petersburg.	Barbadoes.	Delhi.
London.	Quito.	Batavia.

PROBLEM XVI.

A particular place and the hour of the day at that place being given, to find what hour it is at any other place.

Rule. Bring the place, at which the time is given, to the brass meridian, and set the index of the hour circle to 12; turn the globe till the other place comes to the meridian, and the hours passed over by the index will be the difference of time between the two places. If the place where the hour is sought lie to the east of that wherein the time is given, count the difference of time forward from the given hour; if it lie to the west, reckon the difference of time backward.

Examples. 1. When it is ten o'clock in the morning at London, what hour is it at Petersburg?

Answer. The difference of time is two hours; and, as Petersburgh is eastward of London, this difference must be counted forward, so that it is twelve o'clock at noon at Petersburgh.

Or, the difference of longitude between Petersburg and London is 30° 25′, which multiplied by 4 produces 2 hours 1 minute 40 seconds, the difference of time shewn by the clocks of London and Petersburg; hence, as Petersburg lies to the east of London, when it is ten o'clock in the morning at London, it is one minute and forty seconds past twelve at Petersburg.

2. When it is two o'clock in the afternoon at Alexandria in Egypt, what hour is it at Philadelphia.

Answer. The difference of time is seven hours; and because Philadelphia lies to the west of Alexandria, This difference must be reckoned backward, so that it is seven o'clock in the morning at Philadelphia.

Or,	The longitude of Alexandria is	30° 16′ E.
	The longitude of Philadelphia is	75 19 W.
	Difference of longitude	105 35
		4
	Difference of longitude in time	7. h. 2 m. 20 sec.

the clocks at Philadelphia are slower than those at Alexandria; hence, when it is two o'clock in the afternoon at Alexandria, it is 57 m. 40 sec. past six in the morning at Philadelphia

3 When it is noon at London, what hour is it at Calcutta?

PROBLEM XVII.

A particular place and the hour of the day being given, to find all places on the globe where it is then noon, or any other given hour.

RULE. Bring the given place to the brass meridian, and set the index of the hour circle to 12; then, as the difference of time between the given and required places is always known by the problem, if the hour at the required places be earlier than the hour at the given place, turn the globe eastward till the index has passed over as many hours as are equal to the given difference of time; but, if the hour at the required places be later than the hour at the given place, turn the globe westward till the index passes over as many hours as are equal to the given difference of time; and,

in each case, all the places required will be found under the brass meridian.

Examples. When it is noon at London, at what places is it half past eight o'clock in the morning?

Answer. The difference of time between London, the given place, and the required places, is $3\frac{1}{2}$ hours, and the time at the required places is earlier than that at London; therefore, the required places lie $3\frac{1}{2}$ hours westward of London; consequently by bringing London to the brass meridian, setting the index to 12, and turning the globe eastward till the index passes over $3\frac{1}{2}$ hours, all the required places will be under the brass meridian; as the eastern coast of Newfoundland, Cayenne, part of Paraguay, &c.

Or, the difference of time between London, the given place, and the required places, is 3 hours 30 minutes.

3 h 30 m.
60

4) 210 m.

52°—2
60

4)120

30 m.

The difference of longitude between the place and the required places is 52° 30′. The hour at the required places being earlier than that at the given place, they lie 52° 30′ westward of the given place. Hence, all places situated in 52° 30′ west longitude from London are the places sought, and will be found to be Cayenne, &c. as above.

2. When it is two o'clock in the afternoon at London, at what places is it half past five in the afternoon?

Answer. Here the difference of time between London, the given place, and the required places, is $3\frac{1}{2}$ hours; but the time at the required places is later than at London. The operation will be the same as in example 1, only the globe must be turned $3\frac{1}{2}$ hours towards the west, because the required places will be in east longitude, or eastward

of the given place. The places sought are the Caspian sea, western part of Nova Zembla, the island of Socotra, eastern part of Madagascar, &c.

3. When it is ¾ past four in the afternoon at Paris, where is it noon?

4. When it is ¾ past seven in the morning at Ispahan, where is it noon?

5. When it is noon at Madras, where is it half past six o'clock in the morning?

6. At sea, in latitude 40° north, when it was ten o'clock in the morning by the time-piece, which shows the hour at London, it was exactly nine o'clock in the morning at the ship, by a correct celestial observation. In what part of the ocean was the ship?

7. When it is noon at London, what inhabitants of the earth have midnight?

8. When it is ten o'clock in the morning at London, where is it ten o'clock in the evening?

PROBLEM XVIII.

To find the sun's longitude (commonly called the sun's place in the ecliptic) and his declination.

Rule. Look for the given day in the circle of months on the horizon, against which, in the circle of signs, are the sign and degree in which the sun is for that day. Find the same sign and degree in the ecliptic on the surface of the globe; bring the degree of the ecliptic, thus found, to that part of the brass meridian which is numbered from the equator towards the poles, its distance from the equator, reckoned on the brass meridian, is the sun's declination.—This problem may be performed by the celestial globe, using the same rule.

OR, BY THE ANALEMMA.*

Bring the analemma to that part of the brass meridian which is numbered from the equator towards the poles, and the degree on the brass meridian, exactly above the day of the month, is the sun's declination. Turn the globe till a point of the ecliptic, correspondent to the day of the month, passes under the degree of the sun's declination, that point will be the sun's longitude or place for the given day. If the sun's declination, be north, and increasing, the sun's longitude will be somewhere between Aries and Cancer. If the declination be decreasing, the longitude will be between Cancer and Libra. If the sun's declination be south, and increasing, the sun's longitude will be between Libra and Capricorn; if the declination be decreasing, the longitude will be between Capricorn and Aries.

The sun's longitude and declination are given in the second page of every month, in the Nautical Almanac, for every day in that month: they are likewise given in White's Ephemeris, for every day in the year.

* The Analemma is properly an orthographic projection of the sphere on the plane of the meridian; but what is called the Analemma on the globe, is a narrow slip of paper, the length of which is equal to the breadth of the torrid zone. It is pasted on some vacant place on the globe in the torrid zone, and is divided into months, and days of the months, correspondent to the sun's declination for every day in the year. It is divided into two parts; the right hand part begins at the winter solstice, or December 21st, and is reckoned upwards towards the summer solstice, or June 21st, where the left hand part begins which is reckoned downwards in a similar manner, or towards the winter solstice. On Cary's globes the Analemma somewhat resembles the figure 8. It appears to have been drawn in this shape for the convenience of showing the equation of time, by means of a straight line which passes through the middle of it. The equation of time is placed on the horizon of Bardin's globes.

Examples. 1. What is the sun's longitude and declination on the 15th of April?

Answer. The sun's place is 26° in ♈, declination 10° N.

2. Required the sun's place and declination for the following days?

January 21.	May 18.	September 9.
February 7.	June 11.	October 16.
March 16.	July 11.	November 17.
April 8.	August 1.	December 1.

PROBLEM XIX.

The month and day of the month being given, to find all places of the earth where the sun is vertical on that day; those places where the sun does not set, and those places where he does not rise on the given day.

RULE. Find the sun's declination (by Problem XVIII.) for the given day, and mark it on the brass meridian; turn the globe round on its axis from west to east, and all the places which pass under this mark will have the sun vertical on that day.

Secondly. Elevate the north or south pole, according as the sun's declination is north or south, so many degrees above the horizon as are equal to the sun's declination: turn the globe on its axis from west to east; then, to those places which do not descend below the horizon, in that frigid zone near the elevated pole, the sun does not set on the given day; and to those places which do not ascend above the horizon, in that frigid zone adjoining the depressed pole, the sun does not rise on the given day.

Examples. 1. Find all places of the earth where the sun is vertical on the 11th of May; those places in the north frigid zone where the sun does not set; and those places in the south frigid zone where he does not rise.

Answer. The sun is vertical to St. Anthony, one of the Cape Verd islands, the Virgin Islands, south of St. Domingo. Jamaica, Golconda, &c. All places within eighteen degrees of the north pole will have constant day; and those, if any, within eighteen degrees of the south pole will have constant night.

2. Whether does the sun shine over the north or south pole on the 27th of October? to what places will he be vertical at noon? what inhabitants of the earth will have the sun below their horizon during several revolutions, and to what part of the globe will the sun never set on that day?

3. Find all the places on the earth where the inhabitants have no shadow when the sun is on their meridian, on the first of June.

4. What inhabitants of the earth have their shadows directed to every point of the compass during a revolution of the earth on its axis, on the 15th of July?

5. How far does the sun shine over the south pole on the 14th of November? what places in the north frigid zone are in perpetual darkness? and to what places is the sun vertical?

6. If the sun be vertical at any place on the 15th of April, how many days will elapse before he is vertical a second time at that place?

7. If the sun be vertical at any place on the 20th of August, how many days will elapse before he is vertical a second time at that place?

8. Find all places on the earth where the moon was vertical on the 15th of May, 1808.*

* To perform this example, find the moon's declination on the given day in the Nautical Almanac, and mark it on the brass meridian; all places passing under that degree of declination will have the moon vertical, or nearly so, on the given day. The moon's declination at midnight on the 15th of May 1808 was 14° 34' south.

PROBLEM XX.

A place being given in the torrid zone, to find those two days of the year on which the sun will be vertical at that place.

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles, and mark its latitude; turn the globe on its axis, and observe what two points of the ecliptic pass under that latitude; seek those points of the ecliptic in the circle of signs on the horizon, and exactly against them, in the circle of months, stand the days required.

Examples. 1. On what two days of the year will the sun be vertical at Madras?

Answer. On the 25th of April, and on the 18th of August.

2. On what two days of the year is the sun vertical at the following places?

O'why'hee.	St. Helena.	Sierra Leone.
Friendly Isles.	Rio Janeiro.	Vera Cruz.
Porto Bello.	Barbadoes.	Manilla.

PROBLEM XXI.

The month and the day of the month being given (at any place not in the frigid zones,) to find what other day of the year is of the same length.

Rule. Find the sun's place in the ecliptic for the given day (by Problem XVIII.) bring it to the brass meridian, and observe the degree above it; turn the globe on its axis till some other point of the ecliptic falls under the same degree of the meridian; find this point of the ecliptic on the horizon, and directly against it you will find the day of the month required.

This Problem may be performed by the celestial globe in the same manner.

OR, WITHOUT A GLOBE.

Any two days of the year which are of the same length, will be an equal number of days from the longest or shortest day. Hence, whatever number of days the given day is before the longest or shortest day, just so many days will the required day be after the longest or shortest day, *et contra.*

Examples. 1. What day of the year is of the same length as the 25th of April?

Answer. The 18th of August.

2. What day of the year is of the same length as the 25th of May?

3. If the sun rise at four o'clock in the morning at London on the 17th of July, on what other day of the year will it rise at the same hour?

PROBLEM XXII.

The month, day, and hour of the day being given, to find where the sun is vertical at that instant.

Rule. Find the sun's declination and mark it on the brass meridian; bring the given place to the brass meridian, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; but, if the given time be past noon, turn the globe eastward as many hours as the time is past noon; the place exactly under the degree of the sun's declination will be that sought.

Examples. 1. When it is forty minutes past six o'clock in the morning at London, on the 25th of April, where is the sun vertical?

Answer. Here the given time is five hours twenty minutes before noon; hence the globe

must be turned towards the west till the index has passed over five hours twenty minutes, and under the sun's declination on the brass meridian you will find Madras, the place required.

2. When it is four o'clock in the afternoon at London, on the 18th of August, where is the sun vertical?

Answer. Here the given time is four hours past noon; hence, the globe must be turned towards the east, till the index has passed over four hours; then, under the sun's declination, you will find Barbadoes, the place required.

3. When it is three o'clock in the afternoon at Boston, on the fourth of January, where is the sun vertical?

4. When it is three o'clock in the morning at Paris, on the 11th of April, where is the sun vertical?

PROBLEM XXIII.

The month, day, and hour of the day at any place being given, to find all those places of the earth where the sun is rising, those places where the sun is setting, those places that have noon, that particular place where the sun is vertical, those places that have morning twilight, and those places that have evening twilight, and those places that have midnight.

Rule. Find the sun's declination and mark it on the brass meridian; elevate the north or south pole, according as the sun's declination is north or south, so many degrees above the horizon as are equal to the sun's declination; bring the given place to the brass meridian, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; but, if the given time be past noon, turn the globe eastward as many hours as

the time is past noon; keep the globe in this position; then all places along the western edge of the horizon have the sun rising; those places along the eastern edge have the sun setting; those under the brass meridian, above the horizon, have noon; that particular place which stands under the sun's declination, on the brass meridian, has the sun vertical; all places below the western edge of the horizon, within eighteen degrees, have morning twilight; those places which are below the eastern edge of the horizon, within eighteen degrees, have evening twilight; all the places under the brass meridian, below the horizon, have midnight; all the places above the horizon have day, and those below it have night or twilight.

Examples. 1. When it is fifty-two minutes past four o'clock in the morning at London, on the 5th of March, find all places of the earth where the sun is rising, setting, &c. &c.

Answer. The sun's declination will be found to be $6\frac{1}{4}°$ south; therefore, elevate the south pole $6\frac{1}{4}°$ above the horizon. The given time being seven hours eight minutes before noon (= 12 h. — 4 h. 52 m.) the globe must be turned towards the west till the index has passed over seven hours eight minutes.* Let the globe be fixed in this position; then,

The sun is rising at the western part of the White Sea, Petersburg, the Morea in Turkey, &c.

* The hour circles, in general, are not divided into parts less than a quarter of an hour, but the odd minutes are easily reckoned. In this example, having turned the globe westward till the index has passed over seven hours, then, because four minutes of time make one degree, reckon two degrees on the equator eastward, and turn the globe till they pass under the brass meridian.

Setting at the eastern coast of Kamtschatka, Jesus Island, Palmerston Island, &c. between the Friendly and Society Islands.

Noon at the lake Baikal in Irkoutsk, Cochin China, Cambodia, Sunda Islands, &c.

Vertical at Batavia.

Morning twilight at Sweden, part of Germany, the southern part of Italy, Sicily, the western coast of Africa along the Æthiopian Ocean, &c.

Evening twilight at the north west extremity of North America, the Sandwich Islands, the Society Islands, &c.

Midnight at Labrador, New-York, western part of St. Domingo, Chili, and the western coast of South America.

Day at the eastern part of Russia in Europe, Turkey, Egypt, the Cape of Good Hope, and all the eastern part of Africa, almost the whole of Asia, &c.

Night at the whole of North and South America, the western part of Africa, the British Isles, France, Spain, Portugal, &c.

2. When it is four o'clock in the afternoon at London, on the 25th of April, where is the sun rising, setting, &c. &c.?

Answer. The sun's declination being 13° north, the north pole must be elevated 13° above the horizon; and, as the given time is four o'clock in the afternoon, the globe must be turned four hours toward the east; then the sun will be rising at Owhyhee, &c. setting at the Cape of Good Hope, &c. it will be noon at Buenos Ayres, &c., the sun will be vertical at Barbadoes; and, following the directions in the problem, all the other places are readily found.

3. When it is ten o'clock in the morning at Boston, on the longest day, to what countries is the sun rising, setting, &c. &c.?

PROBLEM XXIV.

To find the time of the sun's rising and setting, and the length of the day and night at any place.

RULE. Find the sun's declination, and elevate the north or south pole, according as the declination is north or south, so many degrees above the horizon as are equal to the sun's declination; bring the given place to the brass meridian, and set the index of the hour circle to twelve; turn the globe eastward till the given place comes to the eastern semi-circle of the horizon, and the number of hours passed over by the index will be the time of the sun's setting: deduct these hours from twelve, and you have the time of the sun's rising; because the sun rises as many hours before twelve as it sets after twelve. Double the time of the sun's setting gives the length of the day, and double the time of rising gives the length of the night.

By the same rule, the length of the longest day, at all places not in the frigid zones, may be readily found; for the longest day at all places in north latitude is on the 21st of June, or when the sun enters Cancer; and the longest day at all places in south latitude is on the 21st of December, or when the sun enters the sign Capricorn.

Examples. 1. What time does the sun rise and set at London on the 17th of July, and what is the length of the day and night?

Answer. The sun sets at 8 and rises at (12—8=) 4; the length of the day is sixteen hours, and the length of the night eight. The learner will readily perceive that, if the time at which the sun rises be given, the time at which it sets, together with the length of the day and night, may be found without a globe; if the length of

the day be given, the length of the night, and the time the sun rises and sets may be found; if the length of the night be given, the length of the day and the time the sun rises and sets are easily known.

2. At what time does the sun rise and set at the following places, on the respective days mentioned, and what is the length of the day and night?

London, 17th of May.
Gibraltar, 22d of July.
Bombay, 29th January.
Botany Bay, 20th February.
Pekin, 20th April.
Cape of Good Hope, 7 Dec.
Cape Horn, 29th January.
Washington, 15th Dec.
Petersburg, 24th of October,
Boston, 18th Aug.

3. Find the time the sun rises and sets at every place on the surface of the globe on the 21st of March, and likewise on the 23d of September.

4. Required the length of the longest day and shortest night at the following places:

London	Paris	Pekin
Petersburg	Vienna	Cape Horn
Aberdeen	Berlin	Washington.

5. How much longer is the 21st of June at Petersburg than at Alexandria?

6. How much longer is the 21st of December at Alexandria than at Petersburg?

7. At what time does the sun rise and set at Spitzbergen on the 5th of April?

PROBLEM XXV.

The length of the day at any place being given, to find the sun's declination, and the day of the month.

RULE. Bring the given place to the brass meridian, and set the index to twelve; turn the globe eastward till the index has passed over as many hours as are equal to half the length of the day; keep the globe from revolving on its axis, and

elevate or depress one of the poles till the given place exactly coincides with the eastern semi-circle of the horizon; the distance of the elevated pole from the horizon, will be the sun's declination: mark the sun's declination, thus found, on the brass meridian; turn the globe on its axis, and observe what two points of the ecliptic pass under this mark; seek those points in the circle of signs on the horizon, and exactly against them, in the circle of months, stand the days of the month required.

Examples. 1. What two days in the year are each sixteen hours long at London, and what is the sun's declination?

Answer. The 24th of May, and the 17th of July. The sun's declination is about 21° north.

2. What two days of the year are each fourteen hours long at London?

3. On what two days of the year does the sun set at half past seven o'clock at Edinburgh?

PROBLEM XXVI.

To find the length of the longest day at any place in the north frigid zone.*

Rule. Bring the given place to the northern point of the horizon, by elevating or depressing the pole, and observe its distance from the north pole on the brass meridian; count the same number of degrees on the brass meridian from the equator towards the north pole, and mark the place where the reckoning ends; turn the globe on its axis, and observe what two points of the ecliptic pass under the above mark; find those

* The south frigid zone being uninhabited (at least we know of no inhabitants) the problem is not applied to that zone; however, the rule is general, reading south for north, and 21st of December for the 21st of June.

points of the ecliptic in the circle of signs on the horizon, and exactly against them, in the circle of months, you will find the days on which the longest day begins and ends. The day preceding the 21st of June is that on which the longest day begins at the given place, and the day following the 21st of June is that on which the longest day ends: the space of time between these days is the length of the longest day.

Examples. 1. What is the length of the longest day at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north.

Answer. The place is 18½° from the pole; the longest day begins on the 14th of May, and ends on the 30th of July; the day is, therefore, seventy-seven days long, that is, the sun does not set during seventy-seven revolutions of the earth on its axis.

2. What is the length of the longest day in the north of Spitzbergen, and on what days does it begin and end?

PROBLEM XXVII.

To find the length of the longest night at any place in the north frigid zone.*

RULE. Bring the given place to the northern point of the horizon, by elevating or depressing the pole, and observe its distance from the north pole on the brass meridian; count the same number of degrees on the brass meridian from the equator towards the south pole, and mark the place where the reckoning ends; turn the globe on its axis, and observe what two points of the

* This problem is equally applicable to any place in the south frigid zone, and the rule will be general by reading south for north, and the contrary; likewise, instead of the 21st of December read the 21st of June.

ecliptic pass under the above mark; find those points of the ecliptic in the circle of signs in the horizon, and exactly against them, in the circle of months, you will find the days on which the longest night begins and ends. The day preceding the 21st of December is that on which the longest night begins at the given place, and the day following the 21st of December, is that on which the longest night ends: the space of time between these days, is the length of the longest night.

Examples. 1. What is the length of the longest night at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north?

Answer. The place is 18½° from the pole; the longest night begins on the 16th of November, and ends on the 27th of January: the night is therefore seventy-three days long, that is, the sun does not rise during seventy-three revolutions of the earth on its axis.

2. What is the length of the longest night at the north of Spitzbergen?

PROBLEM XXVIII.

To find the number of days in which the sun rises and sets at any place in the north frigid zone.*

RULE. Bring the given place to the northern point of the horizon, (by elevating or depressing the pole,) and observe its distance from the north pole on the brass meridian; count the same number of degrees on the brass meridian, from the equator towards the poles northward and southward, and make marks where the reckoning ends; observe what two points of the ecliptic, nearest to Aries, pass under the above marks; these points will shew, upon the horizon, the end of

* The same might be found for a place in the south frigid zone, were that zone inhabited.

the longest night and the beginning of the longest day; during the time between these days the sun will rise and set every twenty-four hours: next observe what two points of the ecliptic, nearest to Libra, pass under the marks on the brass meridian; find these points, as before, in the circle of signs, and against them you will find the day on which the longest day ends at the given place, and the day on which the longest night begins; during the time between these days the sun will rise and set every twenty-four hours.

OR, THUS.

The length of the longest day, by Example 1st, Problem XXVI. is 77 days, the length of the longest night, by Example 1st, Problem XXVII. is 73 days; the sum of these is 150, which deducted from 365, leaves 215 days.

Examples. 1. How many days in the year does the sun rise and set at the north of Spitzbergen?

2. How many days does the sun rise and set at Greenland, in latitude 75° north?

3. How many days does the sun rise and set at the northern extremity of Russia and Asia?

PROBLEM XXIX.

To find in what degree of north latitude, on any day between the 21st of March and the 21st of June, or in what degree of south latitude, on any day between the 23d of September and the 21st of December, the sun begins to shine constantly without setting; and also in what latitude in the opposite hemisphere he begins to be totally absent.

RULE. Find the sun's declination and count the same number of degrees from the north

pole towards the equator, if the declination be north, or from the south pole, if it be south, and mark the point where the reckoning ends; turn the globe on its axis, and all places passing under this mark are those in which the sun begins to shine constantly without setting at that time: the same number of degrees from the contrary pole will point out all the places where twilight or total darkness begins.

Examples. 1. In what latitude north, and at what places does the sun begin to shine without setting during several revolutions of the earth on its axis, on the 14th of May?

Answer. The sun's declination is 18½° north, therefore all places in latitude 71½° north will be the places sought, viz. the north cape in Lapland, the southern part of Nova Zembla, Icy Cape, &c.

2. In what latitude does the sun begin to shine without setting, on the 10th of April.

PROBLEM XXX.

Any number of days not exceeding 182, *being given, to find the parallel of north latitude in which the sun does not set for that time.*

Rule. Count half the number of days from the 21st of June on the horizon, eastward or westward, and opposite to the last day you will find the sun's place in the circle of signs; look for the sign and the degree on the ecliptic, which bring to the brass meridian, and observe the sun's declination; reckon the same number of degrees from the north pole, on that part of the brass meridian which is numbered from the equator towards the poles and you will have the latitude sought.

Examples. 1. In what degree of north latitude, and at what place, does the sun continue above the horizon for seventy-seven days?

Answer. Half the number of days is $38\frac{1}{2}$, and, if reckoned backward, or towards the east, from the 21st of June, will answer to the 14th of May; and if counted forward, or towards the west, will answer to the 30th of July; on either of which days the sun's declination is $18\frac{1}{2}$ degrees north, consequently the places sought are $18\frac{1}{2}$ from the north pole, or in latitude $71\frac{1}{2}$ degrees north: answering to the North Cape in Lapland, the south part of Nova Zembla, Icy Cape, &c.

2. In what degree of north latitude is the longest day 134 days, or 3216 hours in length?

PROBLEM XXXI.

To find the beginning, end, and duration of twilight at any place, on any given day.

RULE. Find the sun's declination for the given day and elevate the north or south pole, according as the declination is north or south, so many degrees above the horizon as are equal to the sun's declination; screw the quadrant of altitude on the brass meridian, over the degree of the sun's declination; bring the given place to the brass meridian, and set the index of the hour circle to twelve: turn the globe eastward till the given place comes to the horizon, and the hours passed over by the index will shew the time of the sun's setting, or the beginning of evening twilight: continue the motion of the globe eastward, till the given place coincides with 18° on the quadrant of altitude below the horizon, the time past over by the index of the hour circle, from the time of the sun's setting will be the duration of evening twilight. The morning twilight is the same length.

Examples. 1. Required the beginning, end, and duration of morning and evening twilight at London, on the 19th of April?

Answer. The sun sets at two minutes past seven, and rises at fifty-eight minutes past four: the duration of twilight is two hours and seventeen minutes; consequently, evening twilight ends at nineteen minutes past nine, and morning twilight begins, or day breaks, at forty-one minutes past two.

2. What is the duration of twilight at London on the 23d of September? what time does dark night begin? and at what time does day break in the morning?

Answer. The sun sets at six o'clock, and the duration of twilight is two hours; consequently, the evening twilight ends at eight o'clock, and the morning twilight begins at four.

3. Required the beginning, end, and duration of morning and evening twilight at Boston, on the 25th of August.

4. Required the beginning, end, and duration of morning and evening twilight at Cape Horn, on the 20th of February.

PROBLEM XXXII.

To find the beginning, end, and duration of constant day or twilight at any place.

Rule. Find the latitude of the given place, and add 18° to that latitude; count the number of degrees correspondent to the sum, on that part of the brass meridian which is numbered from the pole towards the equator, mark where the reckoning ends, and observe what two points of the ecliptic pass under the mark;* that point wherein the

* If, after 18 degrees be added to the latitude, the distance from the pole will not reach the ecliptic, there will be no con-

sun's declination is increasing, will show on the horizon the beginning of constant twilight; and that point wherein the sun's declination is decreasing, will show the end of constant twilight.

Examples. 1. When do we begin to have constant day or twilight at London, and how long does it continue?

Answer. The latitude of London is $51\frac{1}{2}$ degrees north, to which add 18 degrees, the sum is $69\frac{1}{2}$, the two points of the ecliptic which pass under $69\frac{1}{2}$ are two degrees in ♊, answering to the 22d of May, and 29 degrees in ♋, answering to the 21st of July, so that from the 22d of May to the 21st of July, the sun never descends 18 degrees below the horizon of London.

2. When do the inhabitants of the Shetland islands cease to have constant day or twilight?

3. Can twilight ever continue from sun-set to sun-rise at Madrid?

PROBLEM XXXIII.

To find the duration of twilight at the north pole.

Rule. Elevate the north pole so that the equator may coincide with the horizon; observe what point of the ecliptic, nearest to Libra, passes under 18° below the horizon, reckoning on the brass meridian, and find the day of the month correspondent thereto; the time elapsed from the 23d of September to this time will be the duration of evening twilight. Secondly, observe what point of the ecliptic, nearest to Aries, passes under 18° below the horizon, reckoned on the brass meridian, and find the day of the month correspondent thereto; the time elapsed from that day to

stant twilight at the given place: viz. to the given latitude add 18 degrees, and subtract the sum from 90, if the remainder exceed 23 1-2 degrees, there can be no constant twilight at the given place.

the 21st of March will be the duration of morning twilight.

Example. What is the duration of twilight at the north pole, and what is the duration of dark night there?

PROBLEM XXXIV.

To find the sun's meridian altitude at any time of the year at any given place.

Rule. Find the sun's declination, and elevate the pole to that declination; bring the given place to the brass meridian, and count the number of degrees between it and the horizon; these degrees will show the sun's meridian altitude.

Examples. 1. What is the sun's meridian altitude at London on the 21st of June?

Answer. 62 degrees.

2. What is the sun's meridian altitude at London on the 21st of March?

3. What is the sun's least meridian altitude at London?

4. What is the sun's greatest meridian altitude at Boston?

5. What is the sun's meridian altitude at Madras on the 20th of June?

6. What is the sun's meridian altitude at Boston on the 15th of January?

PROBLEM XXXV.

When it is midnight at any place in the temperate or torrid zones, to find the sun's altitude at any place (on the same meridian) in the north frigid zone, where the sun does not descend below the horizon.

Rule. Find the sun's declination for the given day, and elevate the pole to that declination; bring

the place, in the frigid zone, to that part of the brass meridian which is numbered from the north pole towards the equator, and the number of degrees between it and the horizon will be the sun's altitude.

Examples. 1. What is the sun's altitude at the North Cape in Lapland, when it is midnight at Alexandria in Egypt on the 21st of June?

Answer. 5 degrees.

2. When it is midnight to the inhabitants of the island of Sicily on the 22d of May, what is the sun's altitude at the north of Spitzbergen, in latitude 80° north?

PROBLEM XXXVI.

To find the sun's amplitude at any place.

RULE. Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place; find the sun's place in the ecliptic, and bring it to the eastern semi-circle of the horizon; the number of degrees from the sun's place to the east point of the horizon will be the rising amplitude: bring the sun's place to the western semi-circle of the horizon, and the number of degrees from the sun's place to the west point of the horizon will be the setting amplitude.

Examples. 1. What is the sun's amplitude at London on the 21st of June?

Answer. 39° 48′ to the north of the east, and 39° 48′ to the north of the west.

2. On what point of the compass does the sun rise and set at Boston on the 17th of May?

3. On what point of the compass does the sun rise and set at the Cape of Good Hope on the 21st of December?

4. On what point of the compass does the sun rise and set on the 21st of March?

5. On what point of the compass does the sun rise and set at Washington on the 21st of October?

6. On what point of the compass does the sun rise and set at Petersburg on the 18th of December?

PROBLEM XXXVII.

To find the sun's azimuth and his altitude at any place, the day and hour being given.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian, over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe eastward* as many hours as it wants of noon; but, if the given time be past noon, turn the globe westward as many hours as it is past noon; bring the graduated edge of the quadrant of altitude to coincide with the sun's place, then the number of degrees on the horizon, reckoned from the north or south point thereof to the graduated edge of the quadrant, will shew the azimuth; and the number of degrees on the quadrant, counting from the horizon to the sun's place, will be the sun's altitude.

Examples. 1. What is the sun's altitude, and his azimuth from the north, at London, on the first of May, at ten o'clock in the morning?

* Whenever the pole is elevated for the latitude of the place, the proper motion of the globe is from east to west, and the sun is on the east side of the brass meridian in the morning, and on the west side in the afternoon; but, when the pole is elevated for the sun's declination, the motion is from west to east, and the place is on the west side of the meridian in the morning, and on the east side in the afternoon.

Answer. The altitude is 47°, and the azimuth from the north 136°, or from the south 44°.

2. What is the sun's altitude and azimuth at Petersburg on the 13th of August, at half past five o'clock in the morning?

3. What is the sun's azimuth and altitude at Antigua, on the 21st of June, at half past six in the morning, and at half past ten?

PROBLEM XXXVIII.

The latitude of the place, day of the month, and the sun's altitude being given, to find the sun's azimuth and the hour of the day.

RULE. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian, over that latitude; bring the sun's place in the ecliptic to the brass meridian, and set the index of the hour circle to twelve; turn the globe on its axis till the sun's place in the ecliptic coincides with the given degree of altitude on the quadrant; the hours passed over by the index of the hour circle will shew the time from noon, and the azimuth will be found on the horizon, as in the preceding problem.

Examples. 1. At what hour of the day on the 21st of March is the sun's altitude 22¼° at London, and what is his azimuth? The observation being made in the afternoon.

Answer. The time from noon will be found to be 3 hours 30 minutes, and the azimuth 59° 1′ from the south towards the west. Had the observation been made before noon, the time from noon would have been 3½ hours, viz. it would have been 30 minutes past eight in the morning, and the azi-

muth would have been 59° 1′ from the south towards the east.*

2. At what hour on the 9th of March is the sun's altitude 25° at London, and what is his azimuth? The observation being made in the forenoon.

PROBLEM XXXIX.

Given the latitude of the place, and the day of the month, to find at what time the sun is due east or west.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; screw the quadrant of altitude on the brass meridian, over the given latitude, and move the lower end of it to the east point of the horizon; hold the quadrant in this position, and move the globe on its axis till the sun's place comes to the graduated edge of the quadrant; the hours passed over by the index from twelve will be the time from noon when the sun is due east, and at the same time from noon he will be due west.

Examples. 1. At what hours will the sun be due east at London on the 19th of May; at what hour will he be due west; and what will his altitude be at these times?

Answer. The time from 12, when the sun is due east, is four hours 54 minutes; hence the sun is due east at six minutes past seven o'clock in the morning, and due west at 54 minutes past four in the afternoon; the sun's altitude may be

* The learner will observe, that the sun has the same altitude at equal distances from noon; hence it is necessary to say whether the observation be made before or after noon otherwise the problem admits of two answers.

found at the same time, as in Problem XXXVII. In this Example it is 25° 26′.

2. At what hours will the sun be due east and west at London on the 21st of June, and on the 21st of December; and what will be his altitude above the horizon on the 21st of June?

PROBLEM XL.

Given the sun's meridian altitude, and the day of the month, to find the latitude of the place.

Rule. Find the sun's place in the ecliptic, and bring it to that part of the brass meridian, which is numbered from the equator towards the poles; then, if the sun was south* of the observer when the altitude was taken, count the number of degrees from the sun's place on the brass meridian towards the south point of the horizon, and mark where the reckoning ends; bring this mark to coincide with the south point of the horizon, and the elevation of the north pole will shew the latitude. If the sun was north of the observer when the altitude was taken, the degrees must be counted in a similar manner, from the sun's place towards the north point of the horizon, and the elevation of the south pole will shew the latitude.

PROBLEM XLI.

The length of the longest day at any place, not within the polar circles being given, to find the latitude of that place.

Rule. Bring the first point of Cancer or Capricorn to the brass meridian, (according as the

* It is necessary to state whether the sun be north or south of the observer at noon, otherwise the problem is unlimited.

place is on the north or south side of the equator,) and set the index of the hour circle to twelve; turn the globe westward on its axis, till the index of the hour circle has passed over as many hours as are equal to half the length of the day; elevate or depress the pole till the sun's place (viz. Cancer or Capricorn) comes to the horizon; then the elevation of the pole will shew the latitude.

Note. This problem will answer for any day in the year, as well as the longest day, by bringing the sun's place to the brass meridian, and proceeding as above.

Examples. 1. In what degree of north latitude, and at what places is the length of the longest day 16½ hours?

Answer. In latitude 52°, and all places situated on, or near that parallel of latitude, have the same length of the day.

2. In what degree of south latitude, and at what places is the longest day fourteen hours?

PROBLEM XLII.

To find the sun's right ascension, oblique ascension, oblique descension, ascensional difference, and time of rising and setting at any place.

Rule. Find the sun's place in the ecliptic, and bring it to that part of the brass meridian, which is numbered from the equator towards the poles; the degree on the equator cut by the graduated edge of the brass meridian, reckoning from the point Aries eastward, will be the sun's right ascension.

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, bring the sun's place in the ecliptic to the eastern part of the horizon, and the degree or the equa-

tor cut by the horizon, reckoning from the point Aries eastward, will be the sun's oblique ascension. Bring the sun's place in the ecliptic to the western part of the horizon, and the degree on the equator cut by the horizon, reckoning from the point Aries eastward, will be the sun's oblique descension.

Find the difference between the sun's right and oblique ascension; or, which is the same thing, the difference between the right ascension and oblique descension, and turn this difference into time by multiplying by 4; then, if the sun's declination and the latitude of the place be both of the same name, viz. both north or both south, the sun rises before six, and sets after six, by a space of time equal to the ascensional difference; but if the sun's declination and the latitude be of contrary names, viz. the one north and the other south, the sun rises after six, and sets before six.

Examples. 1. Required the sun's right ascension, oblique ascension, oblique descension, ascensional difference, the time of rising and setting at London, on the 15th of April.

Answer. The right ascension is 23° 30′, the oblique ascension is 9° 45′, the ascensional difference (23° 30′—9° 45′ =) 13° 45′ or fifty-five minutes of time; consequently the sun rises fifty-five minutes before 6, or five minutes past 5, and sets fifty-five minutes past 6. The oblique descension is 37° 15′; consequently the descensional difference is (37° 15′—23° 30′ =) 13° 45′, the same as the ascensional difference.

2. What are the sun's right ascension, oblique ascension, and oblique descension, on the 27th of September at London? what is the ascensional difference, and at what time does the sun rise and set?

PROBLEM XLIII.

Given the day of the month, and the sun's amplitude, to find the latitude of the place of observation.

Rule. Find the sun's place in the ecliptic, and bring it to the eastern or western part of the horizon, (according as the eastern or western amplitude is given,) elevate or depress the pole till the sun's place coincides with the given amplitude on the horizon, then the elevation of the pole will show the latitude.

OR THUS:

Elevate the north pole to the complement* of the amplitude, and screw the quadrant of altitude upon the brass meridian, over the same degree; bring the equinoctial point Aries to the brass meridian, and move the quadrant of altitude till the sun's declination for the given day (counted on the quadrant) coincides with the equator; the number of degrees between the point Aries and the graduated edge of the quadrant will be the latitude sought.

Examples. 1. The sun's amplitude was observed to be 39° 48′ from the east towards the north, on the 21st of June; required the latitude of the place?

Answer. 51° 32′ north.

2. The sun's amplitude was observed to be 15° 30′ from the east towards the north, at the same time his declination was 15° 30′; required the latitude?

* The complement of the amplitude is found by substracting the amplitude from 90°. The rule is exactly the same as above; for it is formed from a right angled spherical triangle, the base being the complement of the amplitude, the perpendicular the latitude of the place, and the hypothenuse the complement of the sun's declination.

Answer. The latitude was nothing.

3. On the 29th of May, when the sun's declination was 21° 30′ north, his rising amplitude was known to be 22° northward of the east; required the latitude?

Answer. 12° north.

4. When the sun's declination was 2° north, his rising amplitude was 4° north of the east; required the latitude?

Answer. 60° north.

PROBLEM XLIV.

The day and hour being given when a solar eclipse will happen, to find where it will be visible.

Rule. Find the sun's declination, and elevate the pole agreeably to that declination; bring the place, at which the hour is given, to that part of the brass meridian, which is numbered from the equator towards the poles, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe westward till the index has passed over as many hours as the given time wants of noon; if the time be past noon, turn the globe eastward as many hours as it is past noon, and exactly under the degree of the sun's declination on the brass meridian, you will find the place on the globe where the sun will be vertically eclipsed: at all places within 70 degrees of this place, the eclipse may* be visible, especially if it be a total eclipse.

* When the moon is exactly in the node, and when the axis of the moon's shadow and penumbra pass through the centre of the earth, the breadth of the earth's surface under the penumbral shadow is 70° 20′; but the breadth of this shadow is variable; and, if it be not accurately determined by calculation, it is impossible to tell by the globe to what extent an eclipse of the sun will be visible.

Example. On the 11th of February 1804, at twenty-seven minutes past ten o'clock in the morning at London, there was an eclipse of the sun; where was it visible, supposing the moon's penumbral shadow to extend northward seventy degrees from the place where the sun was vertically eclipsed?

Answer. London, &c.

PROBLEM XLV.

The day and hour being given when a lunar eclipse will happen, to find where it will be visible.

Rule. Find the sun's declination for the given day, and note whether it be north or south; if it be north, elevate the south pole so many degrees above the horizon as are equal to the declination; if it be south, elevate the north pole in a similar manner; bring the place at which the hour is given, to that part of the brass meridian which is numbered from the equator towards the poles, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; if after noon, turn the globe eastward as many hours as it is past noon; the place exactly under the degree of the sun's declination will be the antipodes of the place where the moon is vertically eclipsed. Set the index of the hour circle again to twelve, and turn the globe on its axis till the index has passed over twelve hours; then to all places above the horizon the eclipse will be visible; to those places along the western edge of the horizon the moon will rise eclipsed; to those along the eastern edge she will set eclipsed; and to that place immediately

under the sun's declination the moon will be vertically eclipsed.

Example. On the 26th of January 1804, at fifty-eight minutes past seven in the afternoon, at London, there was an eclipse of the moon; where was it visible?

Answer. It was visible to the whole of Europe, Africa, and the continent of Asia.

PROBLEM XLVI.

To explain the phenomenon of the harvest moon.

Definition 1. The harvest moon in north latitude, is the full moon which happens at, or near, the time of the autumnal equinox; for to the inhabitants of north latitude, whenever the moon is in Pisces or Aries, (and she is in these signs twelve times in a year,) there is very little difference between her times of rising for several nights together, because her orbit is at these times nearly parallel to the horizon. This peculiar rising of the moon passes unobserved at all times of the year, except in September and October; for there can never be a full moon, except the sun be directly opposite to the moon; and as this particular rising of the moon can only happen when the moon is in ♓ Pisces or ♈ Aries, the sun must necessarily be either in ♍ Virgo or ♎ Libra at that time, and these signs answer to the months of September and October.

Definition 2. The harvest moon, in south latitude, is the full moon which happens at, or near, the time of the vernal equinox; for, to the inhabitants of south latitude, whenever the moon is in ♍ Virgo or Libra ♎, (and she is in these signs twelve times in a year,) her orbit is nearly parallel to the horizon; but, when the full moon happens in ♍ Virgo or ♎ Libra, the sun must

be either in ♓ Pisces or ♈ Aries. Hence it appears that the harvest moons are just as regular in south latitude as they are in north latitude, only they happen at contrary times of the year.

Rule for performing the problem. 1. For north latitude. Elevate the north pole to the latitude of the place, put a patch or make a mark in the ecliptic on the point Aries, and upon every twelve* degrees preceding and following that point, till there be ten or eleven marks; bring that mark which is the nearest to Pisces to the eastern edge of the horizon, and set the index to twelve; turn the globe westward till the other marks successively come to the horizon, and observe the hours passed over by the index; the intervals of time between the marks coming to the horizon will shew the diurnal difference of time between the moon's rising. If these marks be brought to the western edge of the horizon in the same manner, you will see the diurnal difference of time between the moon's setting: for, when there is the smallest difference between the times of the moon's rising,† there will be the greatest difference between the times of her setting: and, on the contrary, when there is the greatest difference between the times of the moon's rising, there will be the least difference between the times of her setting.

Note. As the moon's nodes vary their position and form a complete revolution in about nineteen

* The reason why you mark every twelve degrees is, that the moon gains $12^{\circ}\ 11'$ of the sun in the ecliptic every day.

† At London when the moon rises in the point Aries, the ecliptic at that point makes an angle of only fifteen degrees with the horizon; but, when she sets in the point Aries, it makes an angle of sixty-two degrees: and, when the moon rises in the point Libra, the ecliptic, at that point, makes an angle of sixty-two degrees with the horizon; but, when she sets in the point Libra, it only makes an angle of fifteen degrees with the horizon.

years, there will be a regular period of all the varieties which can happen in the rising and setting of the moon during that time. The following table, (extracted from Ferguson's Astronomy,) shews in what years the harvest moons are the least and most beneficial, with regard to the times of their rising, from 1805 to 1860. The columns of years under the letter L, are those in which the harvest moons are the least beneficial, because they fall about the descending node; and those under M are the most beneficial, because they fall about the ascending node.

L	L	L	L	M	M	M	M
1807	1814	1831	1847	1805	1822	1838	1854
1808	1815	1832	1848	1806	1823	1839	1855
1809	1826	1833	1849	1816	1824	1840	1856
1810	1827	1834	1850	1817	1825	1841	1857
1811	1828	1844	1851	1818	1835	1842	1858
1812	1829	1845	1852	1819	1836	1843	1859
1813	1830	1846		1820	1837	1853	1860
				1821			

PROBLEM XLVII.

The day and hour of an eclipse of any one of the satellites of Jupiter being given, to find upon the globe all those places where it will be visible.

Rule. Find the sun's declination for the given day, and elevate the pole to that declination; bring the place at which the hour is given to the brass meridian, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; if after noon, turn the globe eastward as many hours as it is past noon; fix the globe in this position: then,

1. *If Jupiter rise after the sun,** that is, if he be an evening star, draw a line along the eastern

* Jupiter rises after the sun, when his longitude is greater than the sun's longitude.

edge of the horizon with a black lead pencil, this line will pass over all places on the earth where the sun is setting at the given hour; turn the globe westward on its axis till as many degrees of the equator have passed under the brass meridian as are equal to the difference between the sun's and Jupiter's right ascension; keep the globe from revolving on its axis, and elevate the pole as many degrees above the horizon as are equal to Jupiter's declination, then draw another line with a pencil along the eastern edge of the horizon: the eclipse will be visible to every place between these lines, viz. from the time of the sun's setting to the time of Jupiter's setting.

2. *If Jupiter rise before the sun*,* that is, if he be a morning star, draw a line along the western edge of the horizon with a black lead pencil, this line will pass over all places of the earth where the sun is rising at the given hour; turn the globe eastward on its axis till as many degrees of the equator have passed under the brass meridian as are equal to the difference between the sun's and Jupiter's right ascension; keep the globe from revolving on its axis, and elevate the pole as many degrees above the horizon as are equal to Jupiter's declination, then draw another line with a pencil along the western edge of the horizon: the eclipse will be visible to every place between these lines, viz. from the time of Jupiter's rising to the time of the sun's rising.

Example. On the 13th of January 1805, there was an emersion of the first satellite of Jupiter at nine minutes three seconds past five o'clock in the morning, at Greenwich; where was it visible?

Answer. In this example the longitude of the sun exceeds the longitude of Jupiter; therefore Jupiter was a morning star, his declination being

* Jupiter rises before the sun, when his longitude is less than the sun's longitude.

19° 16′ S. and his longitude seven signs 29° 46′, by the Nautical Almanac: his right ascension and the sun's right ascension may be found by the globe; for, if Jupiter's longitude in the ecliptic be brought to the brass meridian, his place will stand under the degree of his declination;* and his right ascension will be found on the equator, reckoning from Aries. This eclipse was visible at Greenwich, the greater part of Europe, the west of Africa, Cape Verd Islands, &c.

TABLE OF EQUATION OF TIME.

Days and Months.	Minutes.		Days and Months.	Minutes.		Days and Months.	Minutes.		Days and Months.	Minutes.	
Jan. 1	4	Clock faster than the Dial.	April 1	4	Clockfaster	Aug. 9	5	Clock faster.	27	16	Clock slower than the Dial.
3	5		4	8		15	4		Nov. 15	15	
5	6		7	2		20	3		20	14	
7	7		11	1		24	2		24	13	
9	8		15	0		28	1		27	12	
12	9		*			31	0		30	11	
15	10		19	1	Clock slower.	*			Dec. 2	10	
18	11		24	2		Sept. 3	1	Clock slower than the Dial.	5	9	
21	12		30	3		6	2		7	8	
25	13		May 13	4		9	3		9	7	
31	14		29	3		12	4		11	6	
Feb. 10	15		June 5	2		15	5		13	5	
21	14		10	1		18	6		16	4	
27	13		15	0		21	7		18	3	
Mar. 4	12		*			24	8		20	2	
8	11		20	1	Clock faster.	27	9		22	1	
12	10		25	2		30	10		24	0	
15	9		29	3		Oct. 3	11		*		
19	8		July 5	4		6	12		26	1	Cl.faster.
22	7		11	5		10	13		28	2	
25	6		23	6		14	14		30	3	
28	5					19	15				

* This is on supposition that Jupiter moves on the ecliptic, and, as he deviates but little therefrom, the solution, by this method, will be sufficiently accurate. To know if an eclipse of any one of the satellites of Jupiter will be visible at any place, we are directed by Nautical Almanac, to "find whether Jupiter be 8° above the horizon of the place, and the sun as much below it."

Dials may be constructed on all kinds of planes, whether horizontal or inclined: a vertical dial may be made to face the south, or any point of the compass. To acquire a complete knowledge of dialling, the gnomonical projection of the sphere, and the principles of spherical trigonometry, must be thoroughly understood; these preliminary branches may be learned from Emerson's Gnomonical Projection, and Keith's Trigonometry. The writers on dialling are very numerous; the last and best treatise on the subject is Emerson's.

Problems performed by the Celestial Globe.

PROBLEM XLVIII.

To find the right ascension and declination of the sun, or a star.*

Rule. Bring the sun or star to that part of the brass meridian which is numbered from the equator towards the poles; the degree on the brass meridian is the declination, and the number of degrees on the equinoctial, between the brass meridian and the point Aries, is the right ascension.

Examples. 1. Required the right ascension and declination of *α Dubhe,* in the back of the great Bear?

Answer. Right ascension 162° 49′ declination 62° 48′ N.

2. Required the right ascensions and declinations of the following stars?

* The right ascensions and declinations of the moon and the planets, must be found from an ephemeris; because, by their continual change of situation, they cannot be placed, on the celestial globe, as the stars are placed.

γ, *Algenib*, in Pagasus. γ, *Rigel*, in Orion.
α, *Scheder*, in Cassiopeia. β, *Bellatrix*, in Orion.

PROBLEM XLIX.

*To find the latitude and longitude of a star.**

Rule. Place the upper end of the quadrant of altitude on the north or south pole of the ecliptic, according as the star is on the north or south side of the ecliptic, and move the other end till the star comes to the graduated edge of the quadrant; the number of degrees between the ecliptic and the star is the latitude: and the number of degrees on the ecliptic, reckoning eastward from the point Aries to the quadrant, is the longitude.

Examples. 1. Required the latitude and longitude of α *Aldebaran* in Taurus?

Answer. Latitude 5° 28′ S. Longitude 2 signs 6° 53′; or 6° 53′ in Gemini.

2. Required the latitudes and longitudes of the following stars?

α, *Markab*, inPegasus. α, *Vega*, in Lyra.
β, *Scheat*, in Pegasus. γ, *Rastaben*, in Draco.

PROBLEM L.

The right ascension and descension of a star, the moon, a planet, or of a comet, being given, to find its place on the globe.

Rule. Bring the given degree of right ascension to that part of the brass meridian which is numbered from the equinoctial towards the poles; then, under the given declination on the brass meridian, you will find the star, or place of the planet.

* The latitudes and longitudes of the planets must be found by an ephemeris.

Examples. 1. What star has 261° 29′ of right ascension, and 52° 27′ north declination?

Answer. β in Draco.

2. On the 20th of August 1805, the moon's right ascension was 91° 3′, and her declination 24° 48′; find her place on the globe at that time.

Answer. In the milky way, a little above the left foot of Castor.

3. What stars have the following right ascensions and declinations?

Right Ascensions.		Declinations.			Right Ascensions.		Declinations.		
7°	19′	55°	26′	N.	83°	6′	34°	11′	S.
11	11	59	38	N.	86	13	44	55	N.
25	54	19	50	N.	99	5	16	26	S.

PROBLEM LI.

The latitude and longitude of the moon, a star, or a planet, given, to find its place on the globe.

Rule. Place the division of the quadrant of altitude marked O, on the given longitude in the ecliptic, and the upper end, on the pole of the ecliptic; then under the given latitude, on the graduated edge of the quadrant, you will find the star, or place of the moon, or planet.

Examples. 1. What star has 0 signs 6° 16′ of longitude, and 12° 36′ N. latitude?

Answer. γ in Pegasus.

2. On the 5th of June 1810, at midnight, the moon's longitude was 3^s. 26° 26′, and her latitude 4° 55′ S.; find her place on the globe.

3. What stars have the following latitudes and longitudes?

Latitudes.	Longitudes.	Latitudes.	Longitudes.
12° 35′ S.	1^s 11° 25′	39° 33′ S.	3^s 11° 13′
5 29 N.	2 6 53	10 4 N.	3 17 21

4. On the first of June 1810, the longitudes and latitudes of the planets were as follow: required their places on the globe?

Longitudes.	Latitudes.	Longitudes.	Latitudes.
♅ 2.14° 7′	0° 32 N.	♃ 1^s 15′ 47	0° 56′ S.
♄ 8 12 20	1 47 N.		

PROBLEM LII.

The day and hour, and the latitude of a place being given, to find what stars are rising, setting, culminating, &c.

RULE. Elevate the pole to the latitude of the place, find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; then, if the time be before noon turn the globe eastward on its axis till the index has passed over as many hours as the time wants of noon; but, if the time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon: then all the stars on the eastern semi-circle of the horizon will be rising, those on the western semi-circle will be setting, those under the brass meridian above the horizon will be culminating, those above the horizon will be visible at the given time and place, those below, will be invisible. If the globe be turned on its axis from east to west, those stars which do not go below the horizon never set at the given place; and those which do not come above the horizon never rise; or, if the given latitude be subtracted from 90 degrees, and circles be described on the globe, parallel to the equinoctial, at a distance from it equal to the degrees in the remainder, they will be the circles of perpetual apparition and occultation.

Examples. 1. On the 9th of February, when it is nine o'clock in the evening at London, what stars are rising, what stars are setting, and what stars are on the meridian?

Answer. Alphacca in the northern Crown is rising; Arcturus and Mirach in Boötes just above the horizon; Sirius on the meridian; Procyon and Castor and Pollux a little east of the meridian. The constellations Orion, Taurus, and Auriga, a little west of the meridian; Markab, in Pegasus, just below the western edge of the horizon, &c.

2. On the 20th of January, at two o'clock in the morning at Boston, what stars are rising, what stars are setting, and what stars are on the meridian?

PROBLEM LIII.

The latitude of a place, day of the month, and hour being given, to place the globe in such a manner as to represent the heavens at that time; in order to find out the relative situations and names of the constellations and remarkable stars.

Rule. Take the globe out into the open air, on a clear star-light night, where the surrounding horizon is uninterrupted by different objects; elevate the pole to the latitude of the place, and set the globe due north and south by a meridian line, or by a mariner's compass, taking care to make a proper allowance for the variation; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to 12; then, if the time be after noon, turn the globe westward on its axis till the index has passed over as many hours as the time is past noon; but, if the time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; fix the globe in this position, then the flat end of a pencil being placed on any star on the globe, so as to point towards the centre, the other end will point to that particular star in the heavens.

PROBLEM LIV.

To find when any star, or planet, will rise, come to the meridian, and set at any given place.

RULE. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; bring the star, (or the planet's place*) to the eastern part of the horizon, and the hours between the sun's place and the brass meridian, will be the time from noon when the star or planet rises. If the sun's place be to the east of the brass meridian, the star or planet will rise before noon; if the sun's place be to the west of the brass meridian, the star or planet will rise after noon. In a similar manner, by bringing the star or planet to the meridian, and western part of the horizon, you will have the times of its culminating and setting.

Examples. 1. At what time will Arcturus rise, come to the brass meridian, and set at London, on the 7th September?

Answer. It will rise at seven o'clock in the morning, come to the meridian at three in the afternoon, and set at eleven o'clock at night.

2. On the first of August 1805, the longitude of Jupiter was seven signs, twenty-six degrees, thirty-four minutes, and his latitude forty-five minutes, N.; at what time did he rise, culminate, and set, at Greenwich, and whether was he a morning or an evening star?

Answer. Jupiter rose at half past two in the afternoon, came to the meridian at about ten minutes to seven, and set at a quarter past eleven in

* The latitude and longitude (or the right ascension and declination) of the planet, must be taken from an ephemeris.

the evening. Here Jupiter was an evening star, because he set after the sun.

3. At what time does Sirius rise, set, and come to the meridian of Boston, on the 31st of January?

PROBLEM LV.

To find the amplitude of any star, its oblique ascension and descension, and its diurnal arch, for any given day.

Rule. Elevate the pole to the latitude of the place, and bring the given star to the eastern part of the horizon; then the number of degrees between the star, and the eastern point of the horizon will be its rising amplitude; and the degree of the equinoctial cut by the horizon will be the oblique ascension: set the index of the hour circle to twelve, and turn the globe westward till the given star comes to the western edge of the horizon; the hours passed over by the index will be the star's diurnal arch, or continuance above the horizon. The setting amplitude will be the number of degrees between the star and the western point of the horizon, and the oblique descension will be represented by that degree of the equinoctial which is intersected by the horizon, reckoning from the point Aries.

Examples. 1. Required the rising and setting amplitude of Sirius, its oblique ascension, oblique descension, and diurnal arch, at London?

Answer. The rising amplitude is twenty-seven degrees to the south of the east; setting amplitude twenty-seven degrees south of the west; oblique ascension 120 degrees; oblique descension seventy-seven degrees; and diurnal arch nine hours six minutes.

2. Required the rising and setting amplitude of Aldebaran, its oblique ascension, oblique descension, and diurnal arch, at London?

PROBLEM LVI.

The latitude of a place given, to find the time of the year at which any known star rises or sets achronically, that is, when it rises or sets at sun setting.

Rule. Elevate the pole to the latitude of the place, bring the given star to the eastern edge of the horizon, and observe what degree of the ecliptic is intersected by the western edge of the horizon, the day of the month answering to that degree will show the time when the star rises at sun-set, and consequently, when it begins to be visible in the evening. Turn the globe westward on its axis till the star comes to the western edge of the horizon, and observe what degree of the ecliptic is intersected by the horizon, as before; the day of the month answering to that degree, will show the time when the star sets with the sun, or when it ceases to appear in the evening.

Examples. 1. At what time does Arcturus rise achronically at Ascra in Bœotia, the birth place of Hesiod; the latitude of Ascra, according to Ptolemy, being thirty-eight degrees forty-five minutes, N.?

Answer. When Arcturus is at the eastern part of the horizon, the eleventh degree of Aries will be at the western part, answering to the first of April, the time when Arcturus rises achronically: and it will set achronically on the 30th of November.

2. At what time of the year does Aldebaran rise achronically at Athens, in thirty-eight degrees N. latitude? and at what time of the year does it set achronically?

PROBLEM LVII.

The latitude of a place given, to find the time of the year at which any known star rises or sets cosmically; that is, when it rises or sets at sun rising.

Rule. Elevate the pole to the latitude of the place, bring the given star to the eastern edge of the horizon, and observe what sign and degree of the ecliptic are intersected by the horizon; the month and day of the month, answering to that sign and degree, will show the time when the star rises with the sun. Turn the globe westward on its axis, till the star comes to the western edge of the horizon, and observe what sign and degree of the ecliptic are intersected by the eastern edge, as before; these will point out, on the horizon, the time when the star sets at sunrising.

Examples. 1. At what time in the year do the Pleiades set cosmically at Miletus in Ionia, the birth place of Thales; and at what time of the year do they rise cosmically; the latitude of Miletus, according to Ptolemy, being thirty-seven degrees N.?

Answer. The Pleiades rise with the sun on the 10th of May, and they set at the time of sun-rising on the 22d of November.

2. At what time of the year does Sirius rise with the sun at London; and at what time of the year will Sirius set when the sun rises?

PROBLEM LVIII.

To find the time of the year when any given star rises or sets heliacally.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian over that latitude; bring the given

star to the eastern edge of the horizon, and move the quadrant of altitude till it intersects the ecliptic twelve degrees below the horizon, if the star be of the first magnitude; thirteen degrees, if the star be of the second magnitude; fourteen degrees, if it be of the third magnitude, &c.: the point of the ecliptic, cut by the quadrant, will show the day of the month, on the horizon, when the star rises heliacally. Bring the given star to the western edge of the horizon, and move the quadrant of altitude till it intersects the ecliptic below the western edge of the horizon, in a similar manner as before; the point of the ecliptic, cut by the quadrant, will show the day of the month, on the horizon, when the star sets heliacally.

Examples. 1. At what time does β Tauri, or the bright star in the Bull's Horn, of the second magnitude, rise and set heliacally at Rome?

Answer. The quadrant will intersect the third of Cancer thirteen degrees below the eastern horizon, answering to the 24th of June; and the seventh of Gemini thirteen degrees below the western horizon, answering to the 28th of May.

2. At what time in the year does Sirius, or the Dog Star, rise heliacally at Alexandria in Egypt; and at what time does it set heliacally at the same place?

Answer. The latitude of Alexandria is thirty-one degrees thirteen minutes north; the quadrant will intersect the twelfth of Leo, twelve degrees below the eastern horizon, answering to the 4th of August; and the second of Gemini, twelve degrees below the western horizon, answering to the 23d of May.

3. At what time of the year does Arcturus rise heliacally at Jerusalem, and at what time does it set heliacally?

PROBLEM LIX.

To illustrate the precession of the equinoxes.

Observations. All the stars in the different constellations continually increase in longitude; consequently, either the whole starry heaven has a slow motion from west to east, or the equinoctial points have a slow motion from east to west. In the time of Meton, the first star in the constellation Aries, now marked β, passed through the vernal equinox, whereas it is now upwards of thirty* degrees to the eastward of it.

Illustration. Elevate the north pole ninety degrees above the horizon, then will the equinoctial coincide with the horizon; bring the pole of the ecliptic† to that part of the brass meridian which is numbered from the north pole towards the equinoctial, and make a mark upon the brass meridian above it; let this mark be considered as the pole of the world, let the equinoctial represent the ecliptic, and let the ecliptic be considered as the equinoctial; then count 38½ degrees, the complement of the latitude of London from this pole upwards, and mark where the reckoning ends, which will be at seventy-five degrees, on the brass meridian, from the southern point of the horizon; this mark will stand over the latitude of London.

Now, turn the globe gently on its axis from east to west, and the equinoctial points will move the same way, while at the same time, the pole

* If the precession of the equinoxes be 50 1-4″ in a year, and if the equinoctial colure passed through β Arietis, 430 years before Christ, the longitude of this star ought now (1821) to be 31° 10′ 53″; for, one year : 50 1-4″ : : 2234 years, (=430 +1821) : 31° 25′ 13″, and this longitude is not far from the truth.

† The pole of the ecliptic is that point on the globe where the circular lines meet.

of the world* will describe a circle round the pole of the ecliptic† of 46° 56 in diameter; this circle will be completed in a Platonic‡ year, consisting of 25,791 years, at the rate of 50¼ seconds in a year, and the pole of the heavens will vary its situation a small matter every year. When 12,895½ years, being half the platonic year, are completed (which may be known by turning the globe half round, or till the point Aries coincides with the eastern point of the horizon,) that point of the heavens which is now 8½ degrees south of the zenith of London will be the north pole, as may be seen by referring to the mark which was made over seventy-five degrees on the meridian.

PROBLEM LX.

To find the distances of the stars from each other in degrees.

Rule. Lay the quadrant of altitude over any two stars, so that the division marked O may be on one of the stars; the degrees between them will shew their distance, or the angle which these stars subtend, as seen by a spectator on the earth.

Examples. 1. What is the distance between Vega in Lyra, and Altair in the Eagle?

Answer. Thirty-four degrees.

2. Required the distance between β in the Bull's Horn, and γ Bellatrix in Orion's shoulder?

3. What is the distance between β in Pollux, and α in Procyon?

* Let it be remembered that the pole of the ecliptic on the globe here represents the pole of the world.

† Take notice that the extremity of the globe's axis here represents the pole of the ecliptic.

‡ A *Platonic year* is a period of time determined by the revolution of the equinoxes: this period being once completed, the ancients were of opinion, that the world was to begin anew, and the same series of things to return over again.

PROBLEM LXI.

To find what stars lie in or near the moon's path, or what stars the moon can eclipse, or make a near approach to.

Rule. Find the moon's longitude and latitude, or her right ascension and declination, in an ephemeris, for several days, and mark the moon's places on the globe, then by laying the thread or quadrant of altitude over these places, you will see nearly the moon's path,* and, consequently, what stars lie in her way.

Examples. 1. What stars were in, or near, the moon's path, on the 10th, 11th, 13th, and 16th December 1805?

10th,	☾'s longitude	♌ 20°	12′ lat.	3°	34′ S.
11th,		♍ 4	22	4	25 S.
13th,		♎ 1	39	5	15 S.
16th,		♏ 10	11	4	26 S.

Answer. The stars will be found to be Cor Leonis or Regulus, Spica Virginis, α in Libra, &c.

2. On the 16th, 17th, 18th, and 19th of May 1810, what stars will lie near the moon's way?

16th,	☾'s right ascen.	206°	47′, declin.	9°	42 S.
17th,		220	43	13	14 S.
18th,		235	22	16	3 S.
19th,		250	38	17	53 S.

* The situation of the moon's orbit for any particular day may be found thus: find the place of the moon's ascending node, in the Ephemeris, mark that place and its antipodes (being the descending node) on the globe; half the way between these points, make marks 5° 20′ on the north and south side of the ecliptic, viz. let the northern mark between the ascending and descending node, and the southern between the descending and ascending node; a thread tied round these four points, will shew the position of the moon's orbit.

PROBLEM LXII.

Given the latitude of the places and the day of the month, to find what planets will be above the horizon after sun setting.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, and bring it to the western part of the horizon, or to ten or twelve degrees below; then look in the Ephemeris for that day and month, and you will find what planets are above the horizon; such planets will be fit for observation on that night.

Example. Were any of the planets visible after the sun had descended ten degrees* below the horizon of London, on the 1st of December 1805? their longitudes being as follow:

☿	$8^s\ 22^\circ\ 30'$	♃	$8^s\ 15^\circ\ 27'$	☾'s longitude
♀	9 23 40	♄	6 24 50	at midnight
♂	8 25 21	♅	6 24 5	$0^s\ 9^\circ$.

Answer. Venus and the moon were visible.

PROBLEM LXIII.

Given the latitude of the place, day of the month, and hour of the night and morning, to find what planets will be visible at that hour.

Rule. Elevate the pole so many degrees above the horizon, as are equal to the latitude of the place; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; then, if the given time be

* The planets are not visible, till the sun is a certain number of degrees below the horizon, and these degrees are variable according to the brightness of the planets. Mercury becomes visible when the sun is about ten degrees below the horizon; Venus, when the sun's depression is five degrees; Mars $11^\circ\ 30'$; Jupiter 10°; Saturn 11°; and the Georgian $17^\circ\ 30'$.

before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but, if the given time be past noon, turn the globe westward on its axis till the index has passed over as many hours as the time is past noon; let the globe rest in this position, and look in the Ephemeris for the longitudes of the planets, and, if any of them be in the signs which are above the horizon, such planets will be visible.

Example. On the first of December 1805, the longitudes* of the planets, by an ephemeris, were as follows: were any of them visible at London at five o'clock in the morning?

☿	$8^s\ 22^\circ\ 30'$	♃	$8\ 15^\circ\ 27'$	☾'s longitude
♀	9 23 40	♄	6 24 50	midnight at
♂	8 25 21	♅	6 24 5	$0^s\ 9^\circ\ 15'$

Answer. Saturn and the Georgium Sidus were visible, and both nearly in the same point of the heavens, near the eastern horizon; Saturn was a little to the north of the Georgian.

PROBLEM LXIV.

The latitude of the place and day of the month given, to find how long Venus rises before the sun when she is a morning star, and how long she sets after the sun when she is an evening star.

Rule. Elevate the pole so many degrees above the horizon, as are equal to the latitude of the place; find the latitude and longitude of Venus in an ephemeris, and mark her place on the globe; find the sun's place in the ecliptic, bring

* It is not neccessary to give the latitudes of the planets in this problem; for, if the signs and degrees of the ecliptic in which their longitudes are situated be above the horizon, the planets will likewise be above the horizon.

it to the brass meridian, and set the index of the hour circle to twelve; then, if the place of Venus be to the right hand of the meridian, she is an evening star; if to the left hand, she is a morning star.

When Venus is an evening star. Turn the globe westward till the sun comes to the western edge of the horizon; the hours passed over by the index will be the time from noon when the sun sets, continue the motion of the globe westward till Venus comes to the western edge of the horizon, and the hours passed over by the index will be the time from noon when Venus sets: the difference between these times will shew how long Venus sets after the sun.

When Venus is a morning star. Turn the globe eastward on its axis till the sun comes to the eastern edge of the horizon; the hours passed over by the index will be the time which the sun rises before noon: continue the motion of the globe eastward till Venus comes to the eastern edge of the horizon, and the hours passed over by the index will be the time which the sun rises before noon: the difference between these times will shew how long Venus rises before the sun.

Note. *The same rule will serve for Jupiter, by marking his place instead of that of Venus.*

Examples. 1. On the first of March 1805, the longitude of Venus was ten signs, eighteen degrees, fourteen minutes, or eighteen degrees, fourteen minutes in Aquarius, latitude 0 degree, fifty-two minutes south; was she a morning or an evening star? If a morning star, how long did she rise before the sun at London; if an evening star, how long did she shine after the sun set?

Answer. Venus was a morning star; the sun rose 5½ hours before noon, or at half past 6; and

Venus rose about 6¼ hours before noon, or at three quarters past 5; consequently, Venus rose three quarters of an hour before the sun.

2. On the 25th of October 1805, the longitude of Jupiter was eight signs, seven degrees, twenty-six minutes, or seven degrees, twenty-six minutes in Sagittarius, latitude 0 degrees, twenty-nine minutes north: whether was he a morning or an evening star? If a morning star, how long did he rise before the sun at London; if an evening star, how long did he shine after the sun set?

Answer. Jupiter was an evening star; the sun set at 5 o'clock, and Jupiter set about twenty minutes after six: consequently, he set one hour and twenty minutes after the sun.

PROBLEM LXV.

The latitude of the place and day of the month being given, to find the meridian altitude of any star or planet.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place; then,

For a star. Bring the given star to that part of the brass meridian which is numbered from the equator towards the poles; the degrees on the meridian contained between the star and the horizon will be the altitude required.

For the moon or a planet. Look in an ephemeris for the planet's latitude and longitude, or for its right ascension and declination, for the given month and day, and mark its place on the globe; bring the planet's place to the brass meridian; and the number of degrees between that place and the horizon, will be the altitude.

* The meridian altitudes of the stars on the globe, in the same latitude, are invariable; therefore, when the meridian altitude of a star is sought the day of the month need not be attended to.

Examples. 1. What is the meridian altitude of Aldebaran in Taurus, at London?

Answer. 54° 36′.

2. What is the meridian altitude of Arcturus in Boötes, at London?

3. On the first of September 1810, the longitude of Mars was 4 signs 14 degrees 41 minutes, and latitude 1 degree 9 minutes north; what was his meridian altitude at Cambridge?

PROBLEM LXVI.

To find all those places on the earth to which the moon will be nearly vertical on any given day.

RULE. Look in an ephemeris for the moon's latitude and longitude for the given day, and mark her place on the globe; bring this place to that part of the brass meridian which is numbered from the equator towards the poles, and observe the degree above it; for all places on the earth having that latitude will have the moon vertical, or nearly so, when she comes to their respective meridians.

Examples. 1. On the 15th of October 1805, the moon's longitude at midnight was 3 signs 29 degrees 14 minutes, and her latitude 1 degree 35 minutes south; over what places did she pass nearly vertical?

Answer. From the moon's latitude and longitude being given, her declination may be found by the globe to be about 19° north. The moon was vertical at Porto Rico, St. Domingo, the north of Jamaica, Owhyhee, &c.

2. On the 20th of December 1810, the moon's longitude at midnight was 6 signs 20 degrees, and her latitude 1 degree 5 minutes north, over what places on the earth did she pass nearly vertical?

PROBLEM LXVII.

Given the latitude of a place, the day of the month, and the altitude of a star, to find the hour of the night, and the star's azimuth.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; bring the lower end of the quadrant of altitude to that side of the meridian* on which the star was situated when observed; turn the globe westward till the centre of the star cuts the given altitude on the quadrant; count the hours which the index has passed over, and they will show the time from noon when the star has the given altitude: the quadrant will intersect the horizon in the required azimuth.

Examples. 1. At London, on the 28th of December, the star Deneb in the Lion's tail, marked β, was observed to be 40 degrees above the horizon, and east of the meridian, what hour was it, and what was the star's azimuth?

Answer. By bringing the sun's place to the meridian, and turning the globe westward on its axis till the star cuts 40 degrees of the quadrant, east of the meridian, the index will have passed over 14 hours; consequently, the star has 40 degrees of altitude east of the meridian, 14 hours from noon, or at two o'clock in the morning. Its

* It is necessary to know on which side of the meridian the star is at the time of observation, because it will have the same altitude on both sides of it. Any star may be taken at pleasure, but it is best to take one not too near the meridian, because for some time before the star comes to the meridian, and after it has passed it, the altitude varies very little.

azimuth will be 62½ degrees from the south towards the east.

2. At London, on the 28th of December, the star, β, in the Lion's tail, was observed to be westward of the meridian, and to have 40 degrees of altitude; what hour was it, and what was the star's azimuth?

Answer. By turning the globe westward on its axis till the star cuts 40 degrees of the quadrant, west of the meridian, the index will have passed over 20 hours; consequently, the star has 40 degrees of altitude west of the meridian, 20 hours from noon; or eight o'clock in the morning. Its azimuth will be 62½ degrees from the south towards the west.

3. At London, on the 1st of September, the altitude of Benetnach in Ursa Major, marked η, was observed to be 36 degrees above the horizon, and west of the meridian; what hour was it, and what was the star's azimuth?

4. On the 21st of December the altitude of Sirius, when west of the meridian at London, was observed to be 8 degrees above the horizon; what hour was it, and what was the star's azimuth?

5. On the 12th of August, Menkah in the Whale's jaw, marked α, was observed to be 37 degrees above the horizon of London, and eastward of the meridian; what hour was it, and what was the star's azimuth?

PROBLEM LXVIII.

Given the latitude of a place, day of the month, and hour of the day, to find the altitude of any star, and its azimuth.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon

the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe eastward on its axis till the index has passed over as many hours as the time wants of noon; if the time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon: let the globe rest in this position, and move the quadrant of altitude till its graduated edge coincides with the centre of the given star; the degrees on the quadrant, from the horizon to the star, will be the altitude; and the distance from the north or south part of the brass meridian to the quadrant, counted on the horizon, will be the azimuth from the north or south.

Examples. 1. What are the altitude and azimuth of Capella, at Rome, when it is five o'clock in the morning on the second of December?

Answer. The altitude is 41 degrees 58 minutes and the azimuth 60 degrees 50 minutes from the north towards the west.

2. Required the altitude and azimuth of Altair in Aquila, on the 6th of October, at nine o'clock in the evening, at London?

3. On what point of the compass does the star Aldebaran bear at the Cape of Good Hope, on the fifth of March, at a quarter past eight o'clock in the evening; and what is its altitude?

Answer. The azimuth is 49 degrees 52 minutes from the north, and its altitude is 22 degrees 30 minutes.

4. Required the altitude and azimuth of Alcyone in the Pleiades, marked η, on the 21st of December, at four o'clock in the morning, at London?

PROBLEM LXIX.

Given the latitude of a place, day of the month, and azimuth of a star, to find the hour of the night and the star's altitude.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; bring the lower end of the quadrant of altitude to coincide with the given azimuth on the horizon, and hold it in that position; turn the globe westward till the given star comes to the graduated edge of the quadrant, and the hours passed over by the index will be the time from noon; the degrees on the quadrant, reckoning from the horizon to the star, will be the altitude.

Examples. 1. At London, on the 28th of December, the azimuth of Deneb in the Lion's tail, marked β, was 62½ degrees from the south towards the west; what hour was it, and what was the star's altitude?

Answer. By turning the globe westward on its axis the index will pass over 20 hours before the star intersects the quadrant; therefore the time will be 20 hours from noon, or eight o'clock in the morning; and the star's altitude will be 40 degrees.

2. At London, on the fifth of May, the azimuth of Cor Leonis, or Regulus, marked α, was 74 degrees from the south towards the west; required the star's altitude, and the hour of the night?

3. On the 8th of October, the azimuth of the star marked β, in the shoulder of Auriga, was 50 degrees from the north towards the east; required its altitude at London, and the hour of the night?

4. On the tenth of Septemoer, the azimuth of the star marked ε, in the Dolphin, was 20 degrees from the south towards the east; required its altitude at London, and the hour of the night?

PROBLEM LXX.

Two stars being given, the one on the meridian, and the other on the east or west part of the horizon, to find the latitude of the place.

Rule. Bring the star which was observed to be on the meridian, to the brass meridian; keep the globe from turning on its axis, and elevate or depress the pole till the other star comes to the eastern or western part of the horizon; then the degrees from the elevated pole to the horizon will be the latitude.

Examples. 1. When the two pointers of the Great Bear, marked α and β, or Dubhe and β, were on the meridian, I observed Vega in Lyra to be rising; required the latitude?

Answer. Twenty-seven degrees north.

2. When Arcturus in Bootes was on the meridian, Altair in the Eagle was rising; required the latitude?

PROBLEM LXXI.

The latitude of the place, the day of the month, and two stars that have the same azimuth, being given, to find the hour of the night.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon

* To find what stars have the same azimuth.—Let a smooth board of about a foot in breadth, and three feet high (or of any height you please,) be fixed perpendicularly upon a stand, draw a straight line through the middle of the board,

the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to one; turn the globe on its axis from east to west till the two given stars coincide with the graduated edge of the quadrant of altitude; the hours passed over by the index will show the time from noon; and the common azimuth of the two stars will be found on the horizon.

Examples. 1. At what hour, at London, on the first of May, will Altair in the Eagle, and Vega in the Harp, have the same azimuth, and what will that azimuth be?

Answer. By bringing the sun's place to the meridian, &c. and turning the globe westward, the index will pass over fifteen hours before the stars coincide with the quadrant; hence they will have the same azimuth at fifteen hours from noon, or at three o'clock in the morning; and the azimuth will be 42½ degrees from the south towards the east.

2. On the 10th of September, what is the hour at London when Deneb in Cygnus, and Markab in Pegasus, have the same azimuth, and what is the azimuth?

parallel to the sides; fix a pin in the upper part of this line, and make a hole in the board at the lower part of the line; hang a thread with a plummet fixed to it, upon the pin, and let the ball of the plummet move freely in the hole made in the lower part of the board; set this board upon a table in a window, or in the open air, and wait till the plummet ceases to vibrate; then look along the face of the board, and those stars which are partly hid from your view by the thread will have the same azimuth.

PROBLEM LXXII.

The latitude of the place, the day of the month, and two stars that have the same altitude, being given, to find the hour of the night.

RULE. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; turn the globe on its axis from east to west, till the two given stars coincide with the given altitude on the graduated edge of the quadrant; the hours passed over by the index will be the time from noon when the two stars have that altitude.

Examples. 1. At what hour at London, on the second of September, will Markab in Pegasus, and α in the head of Andromeda, have each thirty degrees of latitude?

Answer. At a quarter past eight in the evening.

2. At what hour at London, on the fifth of January, will α, Menkar in the Whale's jaw, and α, Aldebaran in Taurus, have each thirty-five dedrees of altitude?

PROBLEM LXXIII.

The altitudes of the two stars having the same azimuth, and that azimuth being given, to find the latitude of the place.

RULE. Place the graduated edge of the quadrant of altitude over the two stars, so that each star may be exactly under its given altitude on the quadrant; hold the quadrant in this position, and elevate or depress the pole till the division in marked 0, on the lower end of the quadrant,

coincides with the given azimuth on the horizon; when this is affected, the elevation of the pole will be the latitude.

Examples. 1. The altitude of Arcturus was observed to be forty degrees, and that of Cor Caroli sixty-eight degrees; their common azimuth at the same time was seventy-one degrees from the south towards the east; required the latitude?

Answer. 51½ degrees north.

2. The altitude of ε in Castor was observed to be thirty degrees, and that of β in Procyon twenty degrees; their common azimuth at the same time was 73½ degrees from the south towards the east; required the latitude?

PROBLEM LXXIV.

The day of the month being given and the hour when any known star rises or sets, to find the latitude of the place.

Rule. Find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but, if the given time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon; elevate or depress the pole till the centre of the given star coincides with the horizon; then the elevation of the pole will shew the latitude?

Examples. 1. In what latitude does ε, Mirach, in Bootes rise at half past twelve o'clock at night, on the 10th of December?

Answer. 51½ degree north.

2. In what latitude does Cor Leonis, or Regulus, rise at ten o'clock at night, on the twenty-first of January?

PROBLEM LXXV.

To find on what day of the year any given star passes the meridian at any given hour.

Rule. Bring the given star to the brass meridian, and set the index to twelve; then, if the given time be before noon,* turn the globe westward till the index has passed over as many hours as the time wants of noon; but, if the given time be past noon, turn the globe eastward till the index has passed over as many hours as the time is past noon; observe that degree of the ecliptic which is intersected by the graduated edge of the brass meridian, and the day of the month answering thereto, on the horizon, will be the day required.

Examples. 1. On what day of the month does Procyon come to the meridian of London at three o'clock in the morning?

Answer. Here the time is nine hours before noon; the globe must therefore be turned nine hours towards the west, the point of the ecliptic intersected by the brass meridian will then be the 9th of ♐, answering nearly to the first of December.

2. On what day of the month, and in what month, does α, Alderamin, in Cepheus, come to the meridian of Edinburgh at ten o'clock at night?

* If the given star comes to the meridian at noon, the sun's place will be found under the brass meridian, without turning the globe; if the given star comes to the meridian at midnight, the globe may be turned either eastward or westward till the index has passed over twelve hours.

Answer. Here the time is ten hours after noon; the globe must therefore be turned ten hours towards the east, the point of the ecliptic intersected by the brass meridian will then be the 17th of ♍ answering to 9th of September.

3. On what day of the month, and in what month, does β, Deneb, in the Lion's tail, come to the meridian of Dublin at nine o'clock at night?

PROBLEM LXXVI.

The altitude of two stars being given, to find the latitude of the place.

Rule. Substract each star's altitude from ninety degrees; take successively the extent of the number of degrees contained in each of the remainders, from the equinoctial with a pair of compasses; with the compasses thus extended, place one foot successively in the centre of each star, and describe arches on the globe with a black lead pencil; these arches will cross each other in the zenith; bring the point of intersection to that point of the brass meridian which is numbered from the equinoctial towards the poles, and the degree above it will be the latitude.

Examples. 1. At sea, in north latitude, I observed the altitude of Capella to be thirty degrees, and that of Aldebaran thirty-five degrees; what latitude was I in?

Answer. With an extent of sixty degrees, (=90°—30°) taken from the equinoctial, and one foot of the compass in the centre of Capella, describe an arch towards the north; then with fifty-five degrees, (=90° 35°,) taken in a similar manner, and one foot of the compasses in the centre of Aldebaran, describe another arch, crossing the former; the point of intersection brought to the

brass meridian will shew the latitude to be 20½ degrees north.

2. The altitude of Markab in Pegasus was thirty degrees, and that of Altair in the Eagle at the same time, was sixty-five degrees; what was the latitude, supposing it to be north?

Answer. Twenty nine degrees north.

PROBLEM LXXVII.

The meridian altitude of a known star being given at any place, to find the latitude.

Rule. Bring the given star to that part of the brass meridian which is numbered from the equinoctial towards the poles; count the number of degrees in the given altitude, on the brass meridian, from the star towards the south part of the horizon, and mark where the reckoning ends; elevate or depress the pole till this mark coincides with the south point of the horizon, and the elevation of the north pole above the north point of the horizon will shew the latitude.

Examples. 1. In what degree of north latitude is the meridian altitude of Aldebaran 52½ degrees?

Answer. Fifty-three degrees, thirty-six minutes north.

2. In what degree of north latitude is the meridian altitude of β, one of the pointers in Ursa Major, ninety degrees?

PROBLEM LXXVIII.

To find the time of the moon's southing, or coming to the meridian of any place, on any given day of the month.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the

given place; find the moon's latitude and longitude, or her right ascension and declination, from an ephemeris, and mark her place on the globe; bring the sun's place to the brass meridian, and set the index of the hour circle to twelve; turn the globe westward till the moon's place comes to the meridian, and the hours passed over by the index will show the time from noon when the moon will be upon the meridian.

PROBLEM LXXIX.

To determine the place, and describe the path of a Comet among the fixed stars.

Rule. Observe the distance of the comet from two fixed stars, where latitudes and longitudes are known; then from the distance thus ascertained, calculate the places of the comet by spherical trigonometry.

An easy method of finding and tracing out the place of a Comet mechanically.

Rule. Find two stars in the same line with the comet, by stretching a thread before the eye over all three; then do the same by two other stars and the comet; this done, take a celestial globe, or a planisphere, and draw a line upon it through the two former stars, then through the two latter ones; so shall the intersection of the two lines be the place of the comet at that time. If this process be repeated every evening, and all the points of intersection connected, it will shew the path of the comet in the heavens.

PROBLEM LXXX.

To find the sun's altitude by placing the globe in the sun-shine.

Rule. Place the globe on a truly horizontal plane, stick a needle perpendicularly over the north pole, in the direction of the axis of the globe, and turn the pole towards the sun, so that the shadow of the needle may fall upon the middle of the brass meridian: then elevate or depress the pole till the needle casts no shadow; for then it will point directly to the sun; the elevation of the pole above the horizon will be the sun's altitude.

PROBLEM LXXXI.

To find the sun's declination, his place in the ecliptic, and his azimuth, by placing the globe in the sun-shine.

Rule. Place the globe upon a truly horizontal plane, in a north and south direction by a meridian line, and elevate the pole to the latitude of the place; then, if the sun shine beyond the north pole, his declination is as many degrees north as he shines over the pole; if the sun do not shine so far as the north pole, his declination is as many degrees south as the enlightened part is distant from the pole. The sun's declination being found, his place may be determined by Problem XVIII.

Stick a needle in the parallel of the sun's declination for the given day, and turn the globe on its axis till the needle casts no shadow; fix the globe in this position, and screw the quadrant of altitude over the latitude; bring the graduated edge of the quadrant to coincide with the sun's place, or the point where the needle is fixed, and the degree on the horizon will show the azimuth.

PROBLEM LXXXII.

To draw a meridian line upon a horizontal plane, and to determine the four cardinal points of the horizon.

Rule. Describe several circles from the centre of the horizontal plane, in which centre fix a straight wire perpendicular to the plane; mark in the morning where the end of the shadow touches one of the circles; in the afternoon mark where the end of the shadow touches the same circle; divide the arch of the circle contained between these two points into two equal parts; a line drawn from the point of division to the centre of the plane will be a true meridian, or north and south line; and, if this line be bisected by a perpendicular, that perpendicular will be an east and west line: thus you will have the four cardinal points; but, to be very exact, the plane must be truly horizontal, the wire must be exactly perpendicular to the plane, and the extremity of its shadow must be compared not only upon one of the circles, as above described, but upon several of them.

PROBLEM LXXXIII.

To find the time of the year when the sun or moon will be liable to be eclipsed.

Rule. 1. Find the place of the moon's nodes, the time of new moon, and the sun's longitude at that time, by an ephemeris;* then, if the sun be within seventeen degrees of the moon's node, there will be an eclipse of the sun.

2. Find the place of the moon's nodes, the time of full moon, and the sun's longitude at that time, by an ephemeris; then, if the sun's longi-

* White's Ephemeris, or Nautical Almanac.

tude be within twelve degrees of the moon's nodes, there will be an eclipse of the moon.

Example. On the 15th of January 1805, there was a full moon, at which time the place of the moon's node was ♑ 25° 54′, and the sun's longitude ♑ 25°; did an eclipse of the moon happen at that time?

Answer. Here the sun was nearly in the moon's node, therefore a total eclipse of the moon took place: for, when the sun is in one of the moon's nodes at the time of full moon, the moon is in the other node, and the earth is directly between them; the moon's place was consequently about 25° in Cancer.

A Table of the Latitudes and Longitudes of some of the Principal Places in the World, with the Countries in which they are situated.—N. B. The Longitudes are reckoned from Greenwich Observatory.

A.

Names of Places.	*Country or Sea.*	*Lat.* ° ′			*Long.* ° ′		
Aberdeen	Scotland	57	9	N.	2	28	W.
Acapulco	Mexico	17	10	N.	101	45	W.
Achen	Sumatra I.	5	22	N.	95	40	E.
Adrianople	Turkey	41	10	N.	26	30	E.
Adventure Bay	New Holland	43	23	S.	147	30	E.
Alderney I.	English Channel	49	48	N.	2	15	W.
Aleppo	Syria	35	45	N.	37	20	E.
Alexandretta	Syria	36	35	N.	36	14	E.
Alexandria	Egypt	31	13	N.	29	55	E.
Algiers	Africa	36	49	N.	2	13	E.
Alicant	Spain	38	21	N.	0	30	W.
Amboyna I.	Moluccas	4	25	N.	127	20	E.
Amiens	France	49	53	N.	2	18	E.
Amsterdam	Holland	52	22	N.	4	51	E.
Amsterdam I.	Pacific Ocean	21	9	S.	174	46	W.
Angers	France	47	28	N.	0	33	W.
Angra	Tercera Azore I.	38	39	N.	27	12	W.
Annapolis	Nova Scotia	44	52	N.	64	5	W.
Antwerp	Netherlands	51	13	N.	4	23	E.
Archangel	Russia	64	34	N.	38	58	E.
Ascension I.	S. Atlantic	7	76	S.	14	21	W.
Astracan	Russia	46	21	N.	48	8	E.
Athens	Turkey Europe	38	5	N.	23	52	E.
St. Augustine	Madagascar I.	23	35	S.	43	8	E.
St. Augustine	East Florida	30	10	N.	81	34	W.
Cape St. Augustine	Brazil	8	48	S.	35	5	W.
Ava	Asia	21	30	N.	96	0	E.
Cape Ava	Japan	34	45	N.	140	55	E.
Avignon	France	43	57	N.	4	48	E.

B.

Names of Places.	*Country or Sea.*	*Lat.* ° ′			*Long.* ° ′		
Babelmandel Straits	Red Sea	12	50	N.	43	45	E.
Babylon (Ancient)	Syria	33	0	N.	42	46	E.
Balasore	Hindoostan	21	20	N.	86	0	E.
Banca I. (South End)	Indian Ocean	3	15	S.	107	10	E.
Bantry Bay	Ireland	51	26	N.	10	10	W.
Barbadoes Island (Bridgetown)	Caribb. Sea	13	0	N.	49	50	W.
Barcelona	Spain	41	23	N.	2	11	E.
Basil	Switzerland	47	35	N.	7	29	E.
Basse Terre	Gaudaloupe	15	59	N.	61	54	W.
Bastia	Corsica	42	42	N.	9	25	E.
Batavia	Java I.	6	11	S.	106	52	E.
Bayonne	France	43	29	N.	1	30	W.
Bussora or Bassora	Turkey	30	45	N.	47	0	E.
Bencoolen	Sumatra I.	3	49	S.	102	10	E.
Bergen	Norway	60	24	N.	5	20	E.
Bilboa	Spain	43	26	N.	3	23	W.
Blanco (Cape)	Africa	20	55	N.	17	10	W.
Bombay I.	India	18	57	N.	72	38	E.
Boston	America	42	23	N.	71	3	W.
Botany Bay	New Holland	34	0	S.	151	23	E.
Boulogne	France	50	43	N.	1	47	E.
Bourbon I.	Indian Ocean	20	52	S.	55	30	E.
Bordeaux	France	44	50	N.	0	35	W.
Bremen	Germany	53	5	N.	8	39	E.
Brest	France	48	23	N.	4	29	W.
Brunswick	Germany	52	30	N.	10	24	E.
Brussels	Netherlands	50	51	N.	4	22	E.
Buda	Hungary	47	40	N.	19	20	E.
Buenos Ayres	S. America	34	35	S.	58	31	W.
Burgos	Spain	42	20	N.	3	30	W.

C.

Cadiz or Cales	Spain	36	31	N.	6	12	W.
Cagliari	Sardinia I.	39	25	N.	9	38	E.
Cairo	Egypt	30	3	N.	31	21	E.
Calais	France	50	57	N.	1	51	E.
Calcutta	Bengal	22	35	N.	88	29	E.
Calmar	Sweden	56	40	N.	16	22	E.
Cambray	Netherlands	50	10	N.	3	13	E.
Cambridge	England	52	12	N.	0	4	E.
Canary I. (N.E. point)	Atlantic	28	13	N.	15	39	W.

Names of Places.	*Country or Sea.*	*Lat.*			*Long.*		
		°	′		°	′	
Candia	Candy I.	35	19	N.	25	18	E.
Canton	China	23	8	N.	113	2	E.
Carlscrona	Sweden	56	20	N.	15	26	E.
Carthagena	Spain	37	37	N.	1	8	W.
Carthagena	Terra Firma	10	27	N.	75	27	W.
Cayenne	I. of Cayenne	4	56	N.	3	41	E.
Cherbourgh	France	49	38	N.	1	37	W.
Christiana	Norway	59	55	N.	10	48	E.
Christmas Sound	Terra del Fuego	55	22	S.	70	3	W.
St. Christopher's I.	Caribb. Sea	17	15	N.	62	43	W.
Civita Vecchia	Italy	42	5	N.	11	44	E.
Cochin	India	9	33	N.	75	35	E.
Colongne	Germany	50	55	N.	6	55	E.
Comorin (Cape)	India	7	56	N.	78	5	E.
Constantinople	Turkey	41	1	N.	28	54	E.
Copenhagen	Denmark	55	41	N.	12	35	E.
Cork	Ireland	51	54	N.	8	28	W.
St. Cruz I.	Atlantic Ocean	17	49	N.	64	53	W.

D.

Dantzic	Poland	54	22	N.	18	34	E.
Dardanelles' Straits	Turkey	40	10	N.	26	26	E.
Delhi	Hindoostan	28	37	N.	77	40	E.
St. Domingo	Caribb. Sea	18	20	N.	69	46	W.
Dover	England	51	8	N.	1	18	E.
Drontheim	Norway	63	26	N.	10	22	E.
Dublin	Ireland	53	21	N.	6	6	W.
Dunkirk	France	51	2	N.	2	22	E.

E.

East Cape	New Zealand	37	42	S.	174	30	W.
Edinburgh	Scotland	55	58	N.	3	12	W.
Elsinore	Denmark	56	2	N.	12	37	E.
Embden	Germany	53	12	N.	7	16	E.
Ephesus	Turkey in Asia	38	0	N.	27	53	E.

F.

False Bay	Cape of Good Hope	34	10	S.	18	33	E.
Farewell (Cape)	Greenland	59	30	N.	42	42	W.
Fayal Town	Azore Islands	38	32	N.	28	41	W.
Ferro I. (Town)	Canary Isles	27	47	N.	17	46	W.
Finisterre (Cape)	Spain	42	52	N.	9	17	W.

Names of Places.	*Country or Sea.*	*Lat.*			*Long.*		
		°	′		°	′	
Flamborough Head	England	54	11	N.	0	19	E.
Florence	Italy	43	46	N.	11	2	E.
Flores	Azore Islands	39	34	N.	31	0	W.
Florida (Cape)	S. America	25	47	N.	80	35	W.
N. Foreland	England	51	25	N.	1	28	E.
France (Isle of)	Indian Ocean	20	27	S.	57	16	E.
Francois (Cape)	St. Domingo	19	46	N.	72	18	W.
Funchal	I. of Madeira	32	38	N.	17	6	W.

G.

Geneva	Switzerland	46	12	N.	6	0	E.
Genoa	Italy	44	25	N.	8	36	E.
St. George Town	Bermudas I.	32	22	N.	64	33	W.
Fort St. George	Or Madras	13	5	N.	80	29	E.
Ghent	Netherlands	51	3	N.	3	44	E.
Gibraltar	Spain	36	5	N.	5	22	W.
Goa I.	Malabar Coast	15	31	N.	73	45	E.
Good Hope (Cape)	Africa	34	29	S.	18	23	E.
Gottingen (Observ.)	Germany	51	32	N.	9	53	E.
Greenwich (Obs.)	England	51	29	N.	0	0	
Gaudaloupe	Caribb I.	15	59	N.	61	59	W.
Guernsey	English Channel	49	30	N.	2	52	W.

H.

Haerlem	United Prov.	52	22	N.	4	36	E.
Hague	United Prov.	52	4	N.	4	17	E.
Halifax	Nova Scotia	44	46	N.	63	27	W.
Hamburgh	Germany	53	34	N.	9	55	E.
Hanover	Germany	52	22	N.	9	48	E.
Hatteras (Cape)	N. America	35	12	N.	76	5	W.
Havre de Grace	France	49	29	N.	0	6	E.
Havannah	Isle of Cuba	23	12	N.	82	18	W.
St. Helena (James Town)	Atlantic	15	55	S.	5	49	W.
La Hogue (Cape)	France	49	45	N.	1	57	W.
Horn (Cape)	S. America	55	58	S.	67	26	W.

I. & J.

Jackson (Port)	New Holland	33	52	S.	151	19	E.
Janerio (Rio)	Brazil	22	54	S.	42	44	W.
Java Head	I. of Java	6	49	S.	105	14	E.
Jerusalem	Syria	31	46	N.	35	20	E.

Names of Places.	*Country or Sea*	*Lat.*	*Long.*
		° ′	° ′
Jersey Isle (St. Aubins)	English Channel	49 13 N.	2 12 W.
St. John's	Newfoundland	47 32 N.	52 26 W.
St. Joseph's	California	23 4 N.	109 42 W.
Islamabad	Hindoostan	22 20 N.	91 45 E.
Ispahan	Persia	32 25 N.	52 50 E.
Jodda, or Gidda	Arabia	21 29 N.	39 22 E.
St. Julian (Port)	Patagonia	49 10 S.	68 44 W.
Juan Fernandez	Pacific Ocean	33 45 S.	78 37 W.

K.

Kamtschatka	Siberia	56 20 N.	163 0 E.
St. Kilda	Hebrides	57 47 N.	8 40 W.
Koningsberg	Prussia	54 43 N.	21 35 E.

L.

Ladrone I. (Guam)	Pacific Ocean	13 10 N.	143 15 E.
Land's End	England	50 6 N.	5 54 W.
Leghorn	Italy	43 33 N.	10 16 E.
Leipsic	Germany	51 19 N.	12 20 E.
Leyden	United Prov.	52 8 N.	4 28 E.
Lima	Peru	12 1 S.	76 49 W.
Lisbon	Portugal	38 40 N.	9 10 W.
Liverpool	England	53 24 N.	3 12 W.
Lizard	England	49 57 N.	5 21 W.
London (St.Paul's)	England	51 31 N.	0 6 W.
Louisburg	I. of Cape Breton	45 54 N.	59 54 W.
St. Lucia	Caribb. Sea	13 24 N.	60 51 W.

M.

Macao	China	22 13 N.	113 46 E.
Macassar	I. of Celebes	5 9 S.	119 49 E.
Madrass	India	13 5 N.	80 29 E.
Madrid	Spain	40 59 N.	3 12 W.
Majorca I.	Mediterranean	39 35 N.	2 30 E.
Melacca	India	2 12 N.	102 5 E.
Malta	Mediterranean	35 54 N.	14 28 E.
Manilla	Philippine Is.	14 36 N.	120 53 E.
Marseilles	France	43 18 N.	5 22 E.
Martinico	Caribb. Sea	14 44 N.	61 21 W
Mecca	Arabia	21 40 N.	41 0 E.
Mexico	America	19 26 N.	100 6 W

Names of Places.	*Country or Sea.*	*Lat.*	*Long.*
		° ′	° ′
Milan	Italy	45 28 N.	9 12 E.
Minorca	Mediterranean	39 51 N.	3 54 E.
Mocha	Arabia	13 44 N.	44 4 E.
Montreal	Canada	45 50 N.	73 11 W.
Moscow	Russia	55 46 N.	37 33 E.
Munich	Germany	48 10 N.	11 30 E.

N.

Namur	Netherlands	50 28 N.	4 46 E.
Nankin	China	32 5 N.	118 46 E.
Nantz	France	47 13 N.	1 34 W.
Naples	Italy	40 50 N.	14 17 E.
Naze	Norway	57 58 N.	7 3 E.
Niagara	Canada	43 4 N.	79 8 W.
North Cape	Lapland	71 30 N.	25 57 E.

O.

Oleron I.	France	46 3 N.	1 25 W.
St. Omer	Netherlands	50 45 N.	2 15 E.
Oporto	Portugal	41 10 N.	8 27 W.
Orleans (New)	Louisiana	29 58 N.	89 59 W.
Ortegal (Cape)	Spain	43 46 N.	7 39 W.
Ostend	Netherlands	51 14 N.	2 56 E.
Owhyhee (N.end)	Sandwich Is.	18 54 N.	155 45 W.
Oxford (Observ.)	England	51 45 N.	1 15 W.

P.

Palermo	Sicily	38 10 N.	13 43 E.
Panama	Mexico	8 48 N.	80 21 W.
Paris (Obser.)	France	48 50 N.	2 20 E.
Pegu	India	17 0 N.	96 58 E.
Pekin	China	39 54 N.	116 27 E.
Petersburg	Russia	59 56 N.	30 19 E.
Philadelphia	America	39 57 N.	75 13 W.
Pico I.	Azore Is.	38 29 N.	28 26 W.
Prague	Bohemia	50 5 N.	14 24 E.
Providence	America	41 51 N.	71 26 W.

Q.

Quebec	Canada	46 55 N.	69 53 W.
Quito	Peru	0 13 S.	77 55 W.

R.

Names of Places.	*Country or Sea.*	*Lat.* ° ′	*Long.* ° ′
Rhodes (I. of)	Archipelago	35 27 N.	28 45 E.
Rhode Island	America	41 28 N.	71 30 W.
Riga	Russia	57 5 N.	25 5 E.
Rochelle	France	46 9 N.	1 10 W.
Rome	Italy	41 64 N.	12 29 E.
Rouen	France	49 27 N.	1 5 W.

S.

Samos I.	Archipelago	37 46 N.	27 13 E.
Santa Cruz	Teneriffe	28 27 N.	16 16 W.
Savanah	N. America	32 3 N.	81 24 W.
Scilly Isles	English Channel	49 56 N.	6 46 W.
Senegal	Africa	15 53 N.	16 21 W.
Stockholm	Sweden	59 21 N.	18 4 E.
Suez	Africa	29 50 N.	33 27 E.
Surat	India	21 10 N.	72 22 E.
Surinam	S. America	6 30 N.	55 30 W.

T.

Tangier	Coast of Barbary	35 55 N.	5 45 W.
Teneriffe (Peak)	Canary Islands	28 13 N.	16 29 W.
Tercera I.	Azore Islands	38 45 N.	27 6 W.
Texel I.	United Prov.	53 10 N.	4 59 E.
Tobago	Caribb. Sea	11 15 N.	60 27 W.
Torbay	English Channel	50 33 N.	3 42 W.
Tornea	Lapland	65 51 N.	24 12 E.
Toulouse	France	43 36 N.	1 26 E.
Trieste	Adriatic sea	45 51 N.	14 3 E.
Trincomale	Isle of Ceylon	8 32 N.	81 11 E.
Tripoli	Barbary	32 54 N.	13 5 E.

U. & V.

Upsal	Sweden	59 52 N.	17 42 E.
Uraniburgh	Denmark	55 54 N.	12 52 E.
Ushant I.	Coast of France	48 28 N.	5 4 W.
Valenciennes	France	50 21 N.	3 32 E.
Valencia	Spain	39 30 N.	0 40 W.
Venice	Italy	45 26 N.	12 4 E.
Vera Cruz	Mexico	19 12 N.	97 30 W.
Verd (Cape)	Africa	14 45 N.	17 33 W.

Names of Places.	*Country or Sea.*	*Lat.*	*Long.*
		° ′	° ′
Verona	Italy	45 26 N.	11 18 E.
Versailles	France	48 48 N.	2 7 E.
Vienna (Obser.)	Austria	48 12 N.	16 16 E.
Vincent (Cape)	Spain	37 3 N.	8 59 W.

W.

Wardhuys	Lapland	70 23 N.	31 7 E.
Warsaw	Poland	52 14 N.	21 0 E.
Washington	N. America	38 53 N.	77 43 W.

Y.

York (New)	N. America	40 43 N.	74 10 W.

An Alphabetical List of the Constellations, with the Right Ascension (R.) and Declination (D.) of the middle of each, for the ready finding them on the Globe.—N. B. The letter (N.) or (S.) immediately after the name of the Constellation, shews whether it be north or south of the zodiac. (Z,) the zodaical Constellations.

	R.	D.
Andromeda, N.	14	34 N.
Antinöus, N.	292	0 S.
Apus, vel Avis Indica, S.	252	75 S.
Aquarius. Z.	335	4 S.
Aquila. N.	295	8 N.
Ara. S.	255	55 S.
Aries. Z.	30	22 N.
Argo Navis. S.	115	50 S.
Asterion et Chara. N.	200	40 N.
Auriga. N.	75	45 N.
Boötes. N.	212	20 N.
Brandenburgium Sceptrum. S.	67	15 S.
Camelopardalus. N.	68	70 N.
Cancer. Z.	128	20 N.
Canis Major. S.	105	20 S.
Canis Minor. S.	110	5 N.
Capricornus. Z.	310	20 S.
Caput Medusæ. N.	44	40 N.
Cassiopeia. N.	12	60 N.
Centaurus. S.	200	50 S.
Cepheus. N.	338	65 N.
Cetus. S.	25	12 S.
Cerberus. N.	271	22 N.
Chamœleon S.	175	78 S.
Circinus S.	222	64 S.
Columba Noachi. S.	85	35 S.
Coma Berenices. N.	185	26 N.
Cor Caroli. N.	191	39 N.
Corona Australis. S.	278	40 S.
Corona Borealis. N.	235	30 N.
Corvus. S.	185	15 S.
Crater. S.	168	15 S.
Crux. S.	183	69 S.

	R.	D.
Cygnus. N.	308	42 N.
Delphinus. N.	308	15 N.
Dorado or Xiphias. S.	75	62 S.
Draco. N.	270	66 N.
Equuleus. N.	316	5 N.
Equuleus Pictorius. S.	84	55 S.
Eridanus. S.	60	10 S.
Fornax Chemica. S.	42	30 S.
Gemini. Z.	111	32 N.
Grus. S.	330	45 S.
Hercules. N.	255	22 N.
Horologium. S.	40	60 S.
Hydra. S.	139	8 S.
Hydrus. S.	28	68 S.
Indus. S.	315	55 S.
Lacerta. N.	336	43 N.
Leo, or Leo Major. Z.	150	15 N.
Leo Minor. N.	150	35 N.
Lepus. S.	80	18 S.
Libra. Z.	226	8 S.
Lupus. S.	230	45 S.
Lynx. N.	111	50 N.
Lyra. N.	283	38 N.
Machina Pneumatica. S.	150	32 S.
Microscopium. S.	315	35 S.
Monoceros. S.	110	0
Mons Mænalus. N.	225	5 N.
Mons Mensæ. S.	76	72 S.
Musca. N.	40	27 N.
Musca Australis, vel Apis. S. . . .	185	68 S.
Norma, vel quadra Euclidis. S. . .	242	45 S.
Octans Hadleianus. S.	310	80 S.
Officina Sculptoria. S.	3	38 S.
Orion. S.	80	0
Pavo. S.	302	68 S.
Pegasus. N.	340	14 N.
Perseus. N.	46	49 N.
Phœnix. S.	10	50 S.
Pisces. Z.	5	10 N.
Pisces Notius, vel Australis. S. . . .	335	30 S.
Piscis volans. S.	127	68 S.
Praxiteles, vel cela Sculptoria. S. . .	68	40 S.
Pyxis Nautica. S.	130	30 S.
Reticulus Rhomboidalis. S.	62	62 S.
Robur Caroli. S.	159	50 S.
Sagittarius. Z.	285	35 S.
Sagitta. N.	295	18 N.
Sextans. S.	5	0

	R.	D.
Scorpio. Z.	244	26 S.
Scutum Sobeiski. S.	275	10 S.
Serpens. N.	235	10 N.
Serpentarius. N.	260	13 N.
Taurus. Z.	65	16 N.
Taurus Poniatowski. N.	275	7 N.
Telescopium. S.	278	50 S.
Touchan. S.	359	66 S.
Triangulum. N.	27	32 N.
Triangulum Australis. S.	238	65 S.
Triangulum Minus. N.	22	28 N.
Ursa Major. N.	153	60 N.
Ursa Minor. N.	235	75 N.
Virgo. Z.	195	5 N.
Vulpecula et Anser. N.	300	25 N.
Xiphias. S.	75	62 S.

Fig. 5

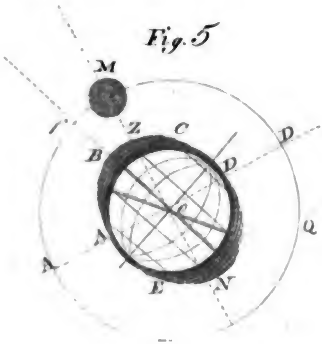


Fig. 4

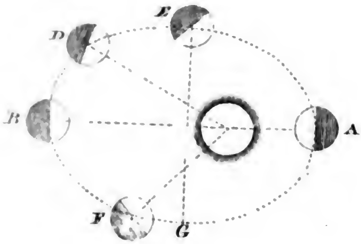


Fig. 6

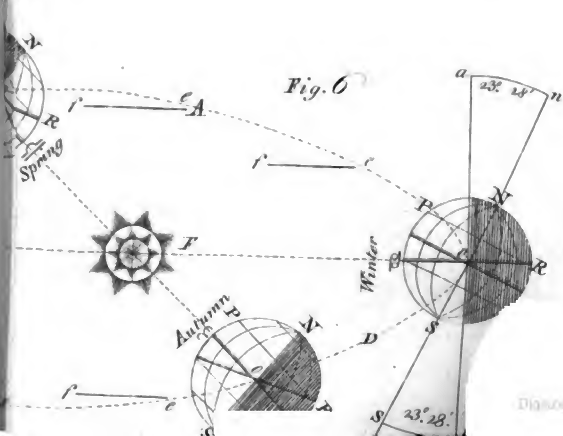
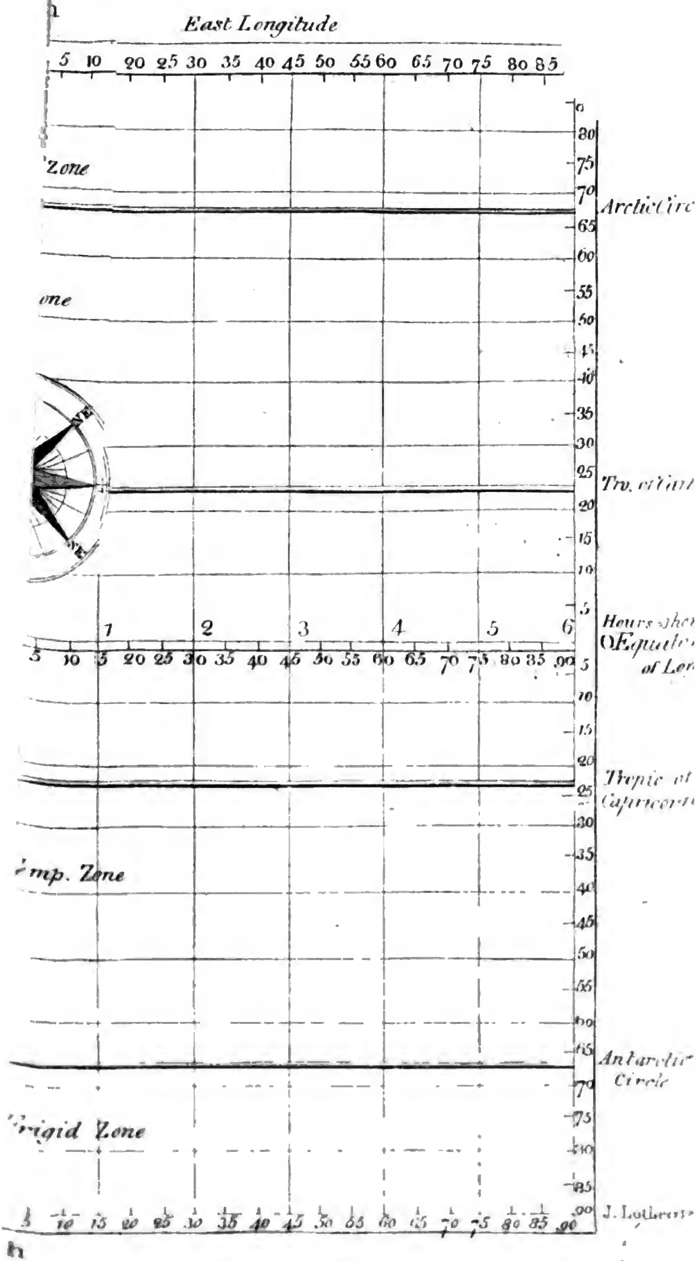


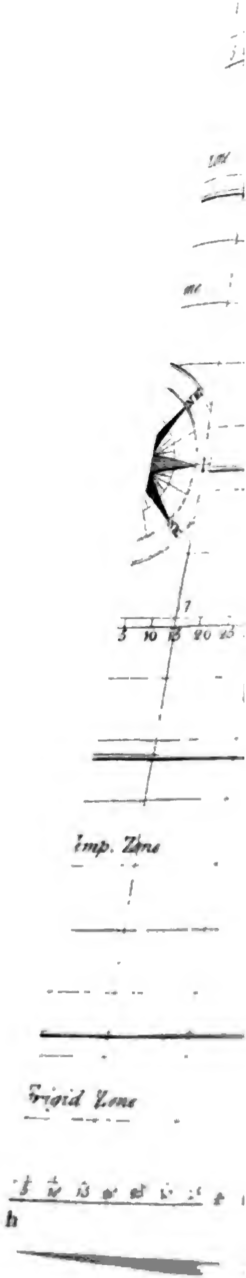
Fig.3.


DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
Aquarius
Pisces
Aries
Taurus
Gemini

M

es of the Globe, Latitude, Longitude, &c.





5 10 15 20 25
7
Temp. Zone
Frigid Zone
h